

PREPARING FOR SEA LEVEL RISE  
DEVELOPMENT OF A SEA LEVEL RISE INITIATIVE

Sea Level Rise Initiative  
Project Compendium  
October 2010



*Photo by: Delaware Shoreline and Waterway Management Section*

*A Compendium of Delaware Coastal Programs' Projects that Address  
Sea Level Rise*



Delaware Coastal Programs

(302) 739-9283



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## THE SEA LEVEL RISE INITIATIVE

In recognition of the importance of the coast to the Nation's commerce, energy development and natural resource protection, the Coastal Zone Act of 1972 was enacted to assist States manage these conflicting uses of coastal areas. At that time, in addition to directing State Coastal Zone Management Programs to address issues of pollution, development, navigation and energy development, the Coastal Zone Act also directed States to prepare for sea level rise.

In recent years, improved climatic and ocean observation systems have made it possible for scientists to better assess the potential for sea level rise and make predictions for the future. These predictions have shown that coastal areas, particularly in the Mid-Atlantic states, will likely see an increased rate of sea level rise. The U.S. Climate Change Science Program's (CCSP) 2009 document, "Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic" recommends that states should prepare for sea level to rise by at least one meter (39 inches) by 2100; the current rate of sea level rise measured by a tide gauge in Lewes Delaware is 13 inches per 100 years. The CCSP prediction is in close agreement with many other predictions by Federal, State and Global agencies and represents a three-fold increase in the historic rate of sea level rise.

This level of sea level rise will have economic, social and environmental effects throughout the State of Delaware. Sea level rise will inundate low lying areas, causing significant losses to tidal wetlands and wildlife habitat. As the high tide line encroaches landward, some important agricultural areas may no longer be suitable for tillage. Sea level rise also can cause higher water tables and salt water intrusion, interfering with the septic systems, drinking water and irrigation water. Most importantly for many coastal communities, sea level rise can increase the effects of storm surge and waves, allowing flooding to occur in areas that may have never previously been susceptible to flooding from storms. All of these potential effects from sea level rise also have implications for coastal access and recreation, transportation networks, public safety and land use patterns.

To help assess, prepare for and minimize the potential impacts of sea level rise, the Delaware Coastal Programs Section of the Delaware Department of Natural Resources and Environmental Control is leading a multi-year Sea Level Rise Initiative. The goal of the Sea Level Rise Initiative is to reduce Delaware's future vulnerability to the effects of sea level rise. This will be accomplished by:

- Providing scientific and technical support for decision-making
- Implementing on-the-ground project in partnership with stakeholders
- Providing educational and outreach opportunities for stakeholders and the public
- Improving existing policies and management practices and/or developing new policies and management practices where necessary

As part of the goal of providing scientific and technical support for decision-making, Delaware Coastal Programs scientists have partnered with the National Wildlife Refuge System, the University of Delaware, local Estuary Programs and other state agencies to fill gaps in our knowledge about coastal storms, tide levels and marsh sediment accretion. This data and information will be used for policy development; communication of this new information is a component of the outreach strategy.

As part of the goal of implementing on the ground projects, Delaware Coastal Programs staff have partnered with the City of New Castle and the Town of Bowers Beach to help them improve their

preparedness for coastal storms and future sea level rise. Related to this effort, and using high resolution elevation data, a real time flood monitoring system is being developed that will greatly improve flood response in coastal communities.

Public involvement and outreach is a critical component of preparing for sea level rise. All of the tools and data developed during the Sea Level Rise initiative will be communicated to the public through websites, presentations, public events, articles and decision-maker workshops. This is detailed in a comprehensive outreach strategy for sea level rise, developed in partnership with the DNREC Watershed Stewardship Division, the Delaware Estuary Program and Delaware Sea Grant.

These projects, along with others described in this document, have been initiated under the Sea Level Rise Initiative to help to build partnerships and capacity, increase resiliency, increase public knowledge of and support for actions to reduce our vulnerability and make decisions based upon the best available science. The Sea Level Rise Initiative is designed to be iterative and will grow and change as new data, outreach and policy needs are identified.

## PURPOSE OF COMPENDIUM OF SEA LEVEL RISE INITIATIVE PROJECTS

The purpose of the Sea Level Rise Initiative Compendium of Projects is to provide an at-a-glance inventory of the projects and initiatives are being conducted as part of the Delaware Coastal Programs' Sea Level Rise Initiative. It is intended to help increase collaboration between agencies, reduce redundancy and overlap in projects relating to sea level rise and to relay information about new (or soon to be available) data, information and tools.

Projects conducted without the assistance or involvement of the Delaware Coastal Programs are not currently reflected in this document. However, there are many other agencies whose work will be essential to preparing for sea level rise and coastal inundation. The Delaware Coastal Programs may in the future consider expanding the scope of this document to include other agencies' work.

Because the projects listed in this document are likely to evolve over time, it is our intent to update this document on a routine basis so that our partner agencies can be kept up to date on sea level rise activities. The most current version of the document will be posted on the Delaware Coastal Programs' sea level rise website.

## FOR MORE INFORMATION

For more information about projects contained within the Sea Level Rise Initiative Compendium, please contact us at (302) 739-9283 or see our website:

<http://www.swc.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx>

## SCIENTIFIC AND TECHNICAL SUPPORT

### BOMBAY HOOK HYDROLOGY/SEDIMENT MOVEMENT STUDY

Coastal areas and natural resources are particularly vulnerable to climate change, especially with respect to accelerated sea level rise, shoreline erosion, increased storm frequency and intensity, changes in rainfall, and related flooding among other potential impacts. Investigation of such impacts, specifically marsh depletion and increased mudflats at Bombay Hook, will be conducted to determine patterns of sediment flux in or out of the depleted marsh area.

Data collection will involve conducting river transects within the Leipsic River using the Acoustic Doppler Current Profiler (ADCP) and associated software to collect and process tide and current data. Water quality will also be monitored, specifically total sediment solids (TSS) to aid in determining sediment fluxes in or out of the depleted marsh area.

#### GEOGRAPHIC LOCATION:

Bombay Hook National Wildlife Refuge.

#### OUTCOME:

This study will result in a written report that includes a summary of results; discussion of data analysis and statistical procedures. Results will be used to predict future changes in marsh depletion and to help determine marsh management techniques to counteract these impacts affecting the tidal marshes at Bombay Hook.

#### ACTIVITIES/SCHEDULE:

1. *Installation of monitoring equipment:* Install 5 water level recorders and 1 Acoustic Doppler Current Profiler.
2. *Perform cross-section current profiles and collect data:* Perform a series of cross-section current profiles at various locations over varying tidal stages and collect water level and ADCP data.
3. *Analyze data and write report:* Data collected to date will be analyzed and interpreted leading to an interim report. This report can be used as a basis for a more detailed study and support future modeling efforts in the Refuge

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	1	May 2009	Completed
<b>2</b>	NA	Ongoing	Ongoing
<b>3</b>	3	March 2011	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS

## COASTAL IMPOUNDMENT ACCRETION RATE STUDY

As an accelerated rate of relative sea-level rise further stresses impounded marshes, there is a greater need to evaluate the long-term sustainability and utility of impoundments in Delaware. In order to do this, baseline data regarding historic sedimentation rates is needed.

Baseline data sets of long-term sedimentation rates in impounded and natural wetlands can be utilized to evaluate the impounded wetlands' ability to achieve optimal habitat benefit under different management strategies and under different sea level rise scenarios

Long-term sedimentation rates over the past 100 and 50 years can be calculated by collecting radioisotopic cores from wetland areas and analyzing them for  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$ . All core sites and the adjacent wetland will be surveyed to tie all data to the tidal datum (NAVD 88). Correlating long-term wetland sedimentation rates to current wetland elevation will enable a detailed analysis of the potential sedimentation deficits that exist within the impoundments, as compared to the reference wetlands. The elevation and sedimentation gradients between the reference and impounded wetlands can be used to calculate potential future elevation trajectories under different sea-level rise and management scenarios.

### GEOGRAPHIC LOCATION:

Monitoring sites were chosen within impounded and reference (natural marsh) sites throughout the State based upon a wetland area change analysis (using a time-series of available imagery), and basins that have been identified as needing detailed study to aid in their management to optimize the future available habitat. Sites that will be studied include: marshes along the Delaware River near New Castle; Ted Harvey Wildlife Area; St. Augustine Wildlife Area; and Primehook National Wildlife Refuge.

### OUTCOME:

When complete, this study will provide information to coastal managers regarding marsh susceptibility to sea level rise under different marsh management scenarios and under different sea level rise scenarios. A long-term comparison of the wetland elevation and sedimentation conditions between the impounded marsh and the "natural" marsh will enable a detailed analysis and comparison of the potential long-term growth conditions and highlight the potential implications for impoundment management that could affect the sustainability of the interior wetlands. This information will allow marsh managers to understand the potential outcomes of sea level rise and adapt their management techniques.

### ACTIVITIES/SCHEDULE:

1. *Initial Impoundment Core Collection:* Radioisotopic cores will be collected from selected marshes. All core sites and adjacent wetlands will be surveyed. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis is scheduled to be complete by December 2009.
2. *New Castle Impoundment Core Collection:* Radioisotopic cores will be collected from 3 impoundments and 2 reference marshes along the Delaware River adjacent to the City of New Castle. All core sites and adjacent wetlands will be surveyed after collection. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis is expected to be complete by December 2010.

3. *Kent County and Lower New Castle County Impoundment Core Collection:* Radioisotopic cores will be collected from Ted Harvey Wildlife Area, St. Augustine Wildlife Area, and Primehook National Wildlife Refuge. The Ted Harvey and St. Augustine sites were selected to expand the scope of the impoundment investigation to include sites along the entire Bay and River coast. All core sites and adjacent wetlands will be surveyed after collection. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis by UD is expected to be completed by December 2011.
4. *Gap Analysis of Delaware Coast:* A gap analysis of the Delaware River and Bay Coast Impoundments and reference marshes will be conducted to identify areas where additional cores should be collected and analyzed. The previously analyzed cores will be examined to evaluate the spatial and temporal variability within the study areas and evaluate the need for additional coring sites. A total of 18 cores will be collected to fill in the identified data gaps and areas of high spatial sedimentation rate variability.

<u>Activity</u>	<u># months req'd for completion</u>	<u>Activity Start Date</u>	<u>Estimated DCP Completion Date</u>	<u>Estimated Laboratory Completion</u>	<u>Status</u>
1	5	November 2008	March 2009	April 2010	In Progress
2	8 - 10	April 2009	November 2009	December 2010	In progress
3	6	December 2009	May 2010	December 2011	Pending
4	8	May 2010	January 2011	December 2012	Pending

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

UD College of Earth, Ocean and Environment

Primehook National Wildlife Refuge (USFWS)

DNREC Division of Fish and Wildlife

## COASTAL MONITORING GAP ANALYSIS

In the last two decades, storms such as Hurricanes Katrina and Ike along the Gulf of Mexico and Floyd and Hugo along the Atlantic Coast of the United States have resulted in significant loss of life, injuries and property damages reaching well over 100 billion dollars. Much of the damage associated with these and other tropical and extra-tropical weather systems is associated with severe coastal flooding. The Delaware coastline is extremely vulnerable to such events, examples being the great March, 1962 storm and the recent coastal flooding incident of May 12, 2008.

As part of a cooperative effort between the University of Delaware and several Delaware State Agencies to better monitor conditions along the Delaware coastline and to provide advance warning of impending coastal flooding events, we propose the completion of a GAP Analysis of pertinent coastal data needs and a comprehensive survey of inland inundation levels during previous coastal flooding events. The GAP Analysis will define the present state of coastal data collection efforts across the state, an “optimum” data collection network and the gap between them, indicating those data that need to be added to the current network. A survey of high water marks from previous coastal flooding events will be used to create a “baseline” data set to aid in understanding the relationships between water levels at tidal monitoring points and inland locations. In this research, an exhaustive inventory of real-time and archived coastal data will be conducted. This inventory will include meteorological, tidal, buoy, water quality and inundation data sources, along with ancillary sources of coastal information (i.e. research publications, modeling work, etc.).

### GEOGRAPHIC LOCATION:

Coastal Delaware.

### OUTCOME:

The final outcome/product will be a report that makes recommendations as to the type of data needed to reach an “optimum” coastal monitoring network, and the spatial placement and temporal resolution of additional sensors that may need to be deployed to reach the optimum configuration. The report is available at:

[http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Gap\\_Analysis\\_Final\\_Report\\_032910.pdf](http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Gap_Analysis_Final_Report_032910.pdf) or <http://www.deos.udel.edu/delawaregap/index.html>

### ACTIVITIES/SCHEDULE:

1. *GAP Analysis Report:* University of Delaware will conduct the analysis and develop a report that makes recommendations as to the type of data needed to reach an “optimum” coastal monitoring network.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	9	March 2010	Completed

### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware

## COASTAL STORM HISTORY

Several coastal communities in Delaware currently experience storm damage, coastal erosion, and other coastal hazard impacts. In efforts to reduce hazard vulnerability that currently exists and that could potentially increase in the future due to climate change impacts, the Delaware Coastal Programs, along with the University of Delaware are compiling data on historical storms, nor'easters, subtropical storms or hurricanes that may have impacted Delaware's coasts in the past.

This data was previously compiled by the University of Delaware for years up through 1974 and a written report is available. This project will focus on updating the storm data from 1974 to 2009.

### GEOGRAPHIC LOCATION:

Coast of Delaware.

### OUTCOME:

Compendium of historical storm data categorized according to the type of storm, physical characteristics and impacts on coastal communities and natural resources. This can perhaps be used to derive specific scenarios to be modeled for the purpose of future adaptation and preparedness. It will also help to identify where outside expertise should be brought in to provide additional technical assistance for resiliency assessment, planning and implementing. Depending on the detail of the data collected, there may be some insight for prediction of the next potential storm, nor'easter or hurricane and the impacts of such events.

### ACTIVITIES/SCHEDULE:

1. *Storm data collection:* Through analysis of historic data sets and communication with local and state officials and the public, historic storm information will be compiled.
2. *Development of Report:* A compilation report will be developed and distributed. The report will include storm data from 1974 to present including all pertinent data.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Contract signed</b>	n/a	Feb 2010	Completed
<b>1</b>	12	Sept 2010	Completed
<b>2</b>	6	March 2011	Pending

### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware

## DEVELOPMENT OF COASTAL INUNDATION MAPS

Sea Level Rise inundation maps are necessary to determine areas and extent of coastal vulnerability to sea level rise, and will be a key component guiding the development of a Statewide Sea Level Rise Adaptation Plan. While it is relatively straight forward to overlay elevated sea level changes onto existing digital elevation models (DEMs), certain factors must be considered. Primarily, mean tide levels vary along the Delaware Bay Coast and any maps developed must take this into consideration. Secondly, solely using sea level rise will not give a true perspective of inundation, since the major concern will be the flooding from coastal storm surges.

To develop these maps (GIS Layers) a statistical evaluation from the existing 2 long-term NOAA tide level datasets of Lewes (Breakwater Harbor) and Delaware City (Reedy Point) will be performed to establish storm surge elevations above Mean Higher High Water (MHHW) for selected return periods (i.e. 10, 25 50, 100-year return periods). Once these are calculated, the current MHHW levels along the length of the coast will be determined using the NOAA VDatum software. These two datasets will be combined to establish the appropriate elevations to use for coastal inundation. After the Delaware Bay coast is completed, a similar effort will be performed for the Inland Bays and Atlantic Coast.

### GEOGRAPHIC LOCATION:

Coastal Delaware

### OUTCOME:

The final outcome/product will be a series of maps in GIS format that will be based on the bare earth LIDAR data. Several scenarios will be developed using on current sea level rise, predicted average sea level rise and predicted maximum sea level rise for the years 2050 and 2100. Estimates of storm surge added to the predicted elevations will also be provided. These surges will be based on historic data and statistical analysis.

### ACTIVITIES/SCHEDULE:

1. *Statistical Analysis of existing tide data:* Based on existing data for Lewes and Delaware City, develop expected storm surge levels for certain return periods.
2. *Determine MHHW for Bay Coast:* Using VDatum, determine MHHW along Delaware Bay coastline corrected to NAVD88
3. *Develop Inundation Maps for Delaware Bay Coast:* Combining the two developed datasets, produce GIS maps for different seal level and storm surge scenarios
4. *Inland Bays and Atlantic Coast Maps:* Repeat 1-3 for Inland Bays and Atlantic Coast.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	<b>2</b>	September, 2009	Completed
<b>2</b>	<1	October, 2009	Completed
<b>3</b>	<b>2</b>	December, 2009	Completed
<b>4</b>	<b>1</b>	January, 2010	Completed

**It is anticipated that all inundation maps will be frequently updated as new information on sea level rise becomes available.**

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

## DIGITAL COAST

The Digital Coast is a nationwide initiative that is designed to ensure the wise use and management of coastal resources by providing coastal managers with data, training, tools and examples to assist them with emerging and priority coastal issues. The partner network identifies Digital Coast priorities and then works together to address coastal issues.

Currently, the Digital Coast partnership is focused on providing data, tools and examples to coastal managers regarding coastal inundation and sea level rise. Projects to address other coastal issues (i.e., marine spatial planning, conservation) will be developed in the future.

One of the goals behind the creation of the Digital Coast was to unify groups that might not otherwise work together and build a strong collaboration of coastal professionals intent on addressing coastal conservation needs. The Digital Coast Partnership Group is currently comprised of representatives from the Association of State Floodplain Managers, the Coastal States Organization, the National Association of Counties, the National States Geographic Information Council, The Nature Conservancy, and the NOAA Coastal Services Center. Delaware Coastal Programs staff has actively served as part of the Coastal States Organization representatives on this project. The National Oceanic and Atmospheric Administration's

(NOAA) Coastal Services Center is the lead organization for Digital Coast efforts.

### OUTCOME:

In the fall of 2009, the Coastal Inundation Toolkit, was released. The toolkit was being developed by the Digital Coast Partnership Group to help communities understand and address coastal inundation issues. Website components include:

- Understand – Learn about inundation basics and common hazard concepts
- Identify – Download the county-specific charts and graphs that tell your story
- Map – Use the steps provided to discover and map areas of potential impact
- Assess – Use inundation maps to assess community risk, vulnerability, and resilience
- Inform – Use risk communication strategies to illicit change
- Discover – See how other communities are addressing this issue

This tool is expected to be of enormous value as a resource tool for the many groups concerned with and working to address coastal flooding and Sea Level Rise issues in Delaware.

Current and future Modules of Digital Coast resources are available at:

<http://www.csc.noaa.gov/digitalcoast/>

## HYDROLOGIC MONITORING OF THE KITTS HUMMOCK AREA

To properly understand the relationships between the Delaware Bay, interior marsh water levels, ponds, impoundments and the drainage ditch network around Kitts Hummock, a comprehensive water level monitoring program will be established. Establishing a water level monitoring network at key locations will aid in the understating the interrelationships between the water bodies and the influence of the drainage network in the community on these water bodies. This baseline monitoring is one of the prerequisite needs for conducting any defensible modeling and evaluation of the effectiveness of any proposed drainage improvements to the Kitts Hummock area. Additional needs prior to modeling include validation of marsh elevations, detailed documentation and assessment of previous storms, and engineering designs of proposed alterations

This baseline network will use a total of 8 Inset HOBO water level recorders in conjunction with the USGS Tide gauge located approximately 5 kilometers south at Bowers Beach and other currently monitored parameters. Two water level recorders will be placed on the north and south sides of Kitts Hummock Road in the primary N/S drainage ditch approximately 250 meters inland from the Delaware Bay. An additional three water level recorders will be used to examine the effects of marsh water elevation and the northern impoundment of the Logan Lane Tract of the Ted Harvey Conservation Area on the open water area of a private property and the South Bay Drive drainage ditch. The final two water level recorders will be installed in open water areas of the marsh northeast of the community of Kitts Hummock to estimate the tidal backwater effects north of Kitts Hummock Road. A final recorder will be housed at the Delaware National Estuarine Research Reserve (DNERR) to measure barometric pressure changes which will be used to atmospherically correct the readings of the water level recorders. The recorders will be surveyed to an accuracy of  $\pm 2$  cm vertical, and maintained and downloaded monthly by staff from the DNERR.

### GEOGRAPHIC LOCATION:

This project encompasses the area surrounding Kitts Hummock, Kent County, DE, including the private marsh lands north and south of the community and the DNREC/DFW Logan Lane Tract of the Ted Harvey Conservation Area.

### OUTCOME:

Once sufficient data has been collected, which includes a minimum of 3 months of data and at least 3 significant storm events, the data will be compiled. Data on rainfall and wave height, period and direction, currently being monitored by the DNERR, will be incorporated into the data set and then the dataset will be analyzed. This analysis will include examining the Bay tide effects on marsh water/drainage ditch elevations; relationships of surrounding water levels on the Thompson open water area; probable pathways of tide related flooding; and a qualitative evaluation of the expected effectiveness of drainage ditches in the area during different tidal cycles/storm events.

### ACTIVITIES/SCHEDULE:

1. *Data Collection:* Install data recorders, survey locations and collect data.
2. *Data Analysis:* Analyze data, run computer simulations, develop qualitative evaluation of storm event drainage scenarios.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	3-5	October 2009	Complete
<b>2</b>	3	December 2009	Complete

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

DNREC Drainage and Stormwater Section

DNREC District Operations

## MARSH LOSS ANALYSIS (INTERIOR OPEN WATER CREATION)

Staff from Bombay Hook NWR contacted the Delaware Coastal Programs for assistance with their 5-year Biologic Review of the refuge. Refuge staff felt that DCP's experience with GIS analysis could help them answer some questions they had about the changing habitat of the refuge. Coastal change, rising sea levels, erosion and land subsidence are increasingly tough issues facing coastal managers, engineers, and planners charged with developing and protecting coastal habitats and communities in vulnerable coastal zones. Understanding these threats depends on early detection, and solutions will require vigorous public debate over engineering solutions vs. strategic retreat. The drastic changes at Bombay Hook National Wildlife Refuge (NWR) may be a harbinger of coast-wide habitat changes in the future.

The coastal areas of Bombay Hook NWR have historically been subjected to significant erosion. Historical shorelines from as far back as 1842 paint a much different picture than exists today. Shores that face the East and Southeast take the worst damage. These areas have the longest fetch allowing the winds to add more power to the waves that break on these shores. For the period 1937-2002, roughly 1700 ft. of erosion occurred along the southern shoreline of Bombay Hook (26 ft/yr). This habitat loss is now coupled with increasing amounts of open water creation in the interior marsh.

Aerial photos from 1979, 1992, and 2002 were examined for expansion of open water areas in the interior marsh. Photos were viewed on a geographic information system and areas of open water were outlined. Results showed that, over the years, open water areas were growing larger and combining together. What had been a mosaic of small areas of open water mixed in vegetated marsh are becoming large tracts of open water with vegetation around the edges. This Study revealed that since 1979, the Refuge has lost a total of 12% of its wetland area; 10% attributed to the creation of interior, open water areas.

No single, direct cause for the wetland loss has yet been identified. Some potential causes including sea level rise, marsh/land subsidence, and snow goose grazing are being looked into. These effects are inter-related and tend to work together to make matters worse. Currently DCP and others are using sediment elevation tables to explore subsidence and sedimentation in regional marshes. It is hoped that if a cause(s) can be determined, adjustments in marsh management can be made to stem the loss of interior area.

This project will investigate the expansion of open water areas in four additional areas throughout the state: the Thousand Acre Marsh region; Blackbird Creek; Milford Neck and Primehook National Wildlife Refuge. For each area, open water areas will be digitized using ArcGIS from historic aerial photographs to determine extent of open water areas over time.

### GEOGRAPHIC LOCATION:

DCP is now expanding the study to other similar marsh areas around the State: 1000 Acre Marsh, Blackbird Creek, Milford Neck Wildlife Area and surrounding private conservation lands; and Prime Hook NWR with nearby areas in Broadkill Beach.

#### OUTCOME:

This project will result in GIS maps of marsh loss over time for the study areas.

It is also hoped that this information can be combined with results from other studies and may shed light on the causes of the wetland loss. This combination of information is expected to lead to management changes that can limit further loss and possibly aid recovery of the marshes.

#### ACTIVITIES/SCHEDULE:

1. *Digitize open water areas:* Bombay Hook.
2. *Digitize open water areas:* 1000 Acre Marsh.
3. *Digitize open water areas:* Blackbird Creek.
4. *Digitize open water areas:* Milford Neck.
5. *Digitize open water areas:* Prime Hook.

Activity	# months req'd for completion	Estimated Completion Date	Status
1.			Complete
2.			Complete
3.			Complete
4.			Complete
5.			Complete

#### AGENCIES INVOLVED:

Delaware Coastal Programs

## MARSH VULNERABILITY INDEX

An index is needed to allow assessment of the long-term viability of Delaware's marshes under differing sea level rise scenarios and to target areas for conservation, restoration and monitoring. The Tidal Marsh Vulnerability Index will be based upon the positive correlation between mean tidal range and elevational growth range of tidal wetland plant species. Biomass sampling, taken from the Mid-Atlantic Wetland Rapid Assessment Method (MidTRAM), will also be incorporated into the Marsh Vulnerability Index to assess marsh health. Once developed, the Sea Level Rise Index for Tidal Marshes tool could be transferred to other states and used for regional comparisons and regional planning.

The Tidal Marsh Vulnerability Index will classify marshes as healthy, degrading or severely degrading. These classifications will be utilized to select areas to conduct detailed sediment accretion rate and other monitoring. Degraded and severely threatened marshes are known to have lower elevations, relative to the tidal prism, and are more prone to catastrophic losses due to sea-level rise and storm events. Understanding the current and historic sedimentation accretion rates of these marshes can help to better predict the longevity and the sediment deficits of these areas and possible management practices that might be implemented to prevent marsh elevation losses (i.e. thin layer application of sediment, vegetation plantings, etc.).

The Tidal Marsh Vulnerability Index, in conjugation with time-series analysis of aerial imagery, will be essential for evaluating wetland vulnerability on a watershed or statewide basis, while enabling the strategic placement of monitoring resources to enhance our efforts to understand the future evolution potential of Delaware's tidal wetlands. All field based monitoring and sampling efforts can be initiated and implemented to evaluate the most severely threatened marsh areas first; the monitoring can then be expanded to encompass other marsh regions as resources become available. Marsh Vulnerability Index classification optimizes the monitoring efforts and resources to the highest levels possible, so the broadest extent of Delaware's tidal wetlands may be evaluate and managed.

### GEOGRAPHIC LOCATION:

Phase I & III will occur in the two components of the Delaware National Estuarine Research Reserve, and the National Estuary Program, Center for the Inland Bays. Phase II & IV will occur in tidal marshes along the Delaware Bay Coast and inland bays.

### OUTCOME:

Phase I will develop a marsh vulnerability index for *Spartina alterniflora* at three test sites located within the Delaware National Estuarine Research Reserve and the National Estuary Program's Center for the Inland Bays. These three target sites encompass all three counties and three different salinity regimes. This phase will use GIS data, aerial photos, LiDAR data and the Statewide Wetland Mapping Program data along with field validation to develop a *Spartina alterniflora* tidal growth range. These site specific values will be compared with the other regions and values the literature to determine if a Statewide or regional Marsh Vulnerability Index can be developed for

*Spartina alterniflora* marshes. Individual marsh polygon elevations will then be compared with the Marsh Vulnerability Index to estimate the sustainability of that particular marsh.

Phase II will develop a statewide Marsh Vulnerability Index for *Spartina alterniflora* marshes. Contiguous areas of *Spartina alterniflora* will be identified using SWMP data and ArcGIS polygons will be created. Marsh elevation and tidal ranges and mean tide elevations will be determined from the LiDAR dataset and/or additional on the ground sampling. Based on the maximum/minimum elevations derived from the Arc/GIS analysis a refined *Spartina alterniflora* tidal growth range will be developed. The *Spartina alterniflora* marshes throughout the State will then be classified using the Marsh Vulnerability Index. The outcome of Phase II is contingent upon Phase I and a positive index created for *Spartina alterniflora*.

Phase III will develop a marsh vulnerability index for other vegetation types within the same three test sites. Indicator species will be identified that are typically found in other areas of coastal Delaware. These species can be homogeneous communities (species specific index) or common heterogeneous communities (composite index). Based on the maximum/minimum elevations derived from the Arc/GIS analysis, a site specific indicator species composite tidal growth range will be developed. These site specific values will be compared with the other regions to determine if a Statewide or regional composite Marsh Vulnerability Index can be developed for marshes dominated by certain indicator species. The individual marsh polygon elevations will be compared with the Marsh Vulnerability Index to estimate the sustainability of that particular marsh.

Phase IV will produce a Statewide Marsh Vulnerability Index for several indicator marshes throughout the State. Contiguous areas of indicator marshes along the Delaware Coast will be identified and these areas will be defined as polygons in Arc/GIS. A random sampling of the sites will be done to insure the proper identification of the species. Mean, median, maximum and minimum elevations will be determined for each marsh polygon, and actual marsh elevation will be determined with LiDAR data. Additional field sampling may be conducted to verify elevations. The tidal ranges and mean tide elevation will be determined for a range of regions along the Delaware Bay coast. Based on the maximum/minimum elevations derived from the Arc/GIS analysis, a refined indicator species tidal growth range (both species specific and composite indexes) will be developed. The indicator species in marshes throughout the State will then be classified based on marsh species structure, larger contiguous marshes will then be classified using the Marsh Vulnerability Index. The outcome of Phase IV is contingent upon Phase I and a positive index created for *Spartina alterniflora*.

#### ACTIVITIES/SCHEDULE:

1. *Phase I:* Develop *Spartina alterniflora* index for DNERR and CIB locations.
2. *Phase II:* Develop *Spartina alterniflora* index for coastal Delaware locations.
3. *Phase III:* Develop multiple species indexes for DNERR and CIB locations.
4. *Phase IV:* Develop multiple species indexes for coastal Delaware locations

<b>Activity</b>	<b># months req' for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	12	December 2010	Fieldwork Complete/ Processing In Progress
<b>2</b>	12	December 2011	In Progress
<b>3</b>	12	March 2012	Pending
<b>4</b>	12	March 2013	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS (Coastal Delaware Refuge Complex)

University of Delaware

## PRIME HOOK NWR SALINITY/NUTRIENT/SEDIMENT/WATER LEVEL STUDY

Coastal areas and natural resources are particularly vulnerable to climate change, especially with respect to accelerated sea level rise, shoreline erosion, increased storm frequency and intensity, changes in rainfall, and related flooding among other potential impacts. Investigation of such impacts, specifically salinity changes, nutrient inputs and sediment transport within the coastal impoundments at Prime Hook, will be conducted to determine the consequences of management practices and natural events.

Data collection will involve installing monitoring equipment to measure salinity and water level, and conducting salinity transects within the impoundments. Water quality will also be monitored, specifically total sediment solids (TSS) and nitrogen/phosphorus compounds to aid in determining sediment and nutrient fluxes in and out of the impoundments.

### GEOGRAPHIC LOCATION:

Prime Hook National Wildlife Refuge.

### OUTCOME:

This study will result in installation of real-time monitoring network; written reports that include summary of results; discussion of data analysis and statistical procedures. Results will be used to quantify current conditions in the impoundments and predict future changes of future management techniques.

### ACTIVITIES/SCHEDULE:

4. *Installation of monitoring equipment:* Install 7 water level and salinity recorders and set up real-time network
5. *Perform salinity transects:* Perform a series of salinity transects within impoundments II & III
6. *Collection of nutrient and sediment data:* Purchase of sampling equipment, design sampling protocols and collect data for seasonal baseline and storm conditions.
7. *Analyze data and write reports:* Data collected will be analyzed and interpreted leading to an interim reports. These report will be used as a basis for a more detailed study and support management efforts of the Refuge

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	2	Oct 2010	Completed
<b>2</b>	24	Oct 2012	Ongoing
<b>3</b>	24	Dec 2012	Pending
<b>4</b>	NA	Ongoing	Ongoing

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS

## SEDIMENT ELEVATION TABLES

Sediment elevation tables (SETs) provide a nondestructive method for making highly accurate and precise measurements of sediment elevation in intertidal and subtidal wetlands over long periods of time, relative to a fixed subsurface datum. Data collected using SETs can be used to determine both the influence of a single meteorological event on sediment surface elevation and a long-term trend in elevation change. This information will help increase our understanding of sedimentation rates in different marshes, sea level rise effects in these marshes, and potential management techniques.

This project will continue to collect data from established SETs within the St. Jones and Blackbird Creek estuaries. These SETs have datasets that began in 2004-2005 for Blackbird Creek and 2004 and 2007 for St. Jones River. The datasets contain total surface elevation change, shallow surface elevation change, sedimentation, deep subsidence, and shallow subsidence trends.

Marsh surface elevation changes are not merely being controlled by sediment deposition or erosion; subsurface processes are playing a major role in controlling elevation. Separating the influences of the biological (root growth), geological (soil compaction) and hydrological processes (groundwater storage) can be very difficult at best. Measurements from the deep benchmark will document and illustrate the effect that subsidence and compaction (the consolidation and dewatering of the fine grained material deep in the marsh sediments) are having on marsh surface elevation, with these changes in the zone of deep subsidence. The shallow benchmark will localize the effects that occur in the root zone (from the surface to ~ 30 to 50 cm below the sediment surface), such as enhanced growth due to nutrient fluxes, decomposition, compaction, dewatering, and pore water fluxes. Thus, it can be determined whether the subsurface influences are occurring (in the root zone or at deeper depths) and make a first approximation of which processes are dominating elevation change.

### GEOGRAPHIC LOCATION:

The project will be conducted within the St. Jones Estuary in Kent County, Delaware and the Blackbird Creek Estuary in New Castle County, Delaware.

### OUTCOME:

This study will result in a written report that includes a summary of results, discussion of data analysis and statistical procedures. Results can then be used to determine both the influence of a single meteorological event on sediment surface elevation and a long-term trend (i.e. decades) in elevation change, as well as make predictions for future elevation changes in our local marshes.

### ACTIVITIES/SCHEDULE:

1. *SET Monitoring:* SETs will be monitored and read in the St. Jones and Blackbird watershed every 3 months, approximately at the end of each season (i.e. fall, winter, etc.) on the same lunar cycle. Readings will take a total of 6 days per monitoring cycle (3 days each for the St. Jones and Blackbird), for a total of 24 field days for the year. Winter readings could be skipped due to high ice volumes on the marsh surface, which negate the ability to reliably measure the marsh surface.
2. *Status and Trends Report:* A status and trends report of the SET data will be drafted and peer reviewed every two years, for both the St. Jones and Blackbird SET networks. The first report will be completed by February 2011. The report will also include a gap analysis on the current coverage of SET networks across the state and highlight the gaps in spatial

distribution, and make recommendations for future SET placements that could help increase the wetland monitoring.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	On going	Expected 15 to 20 year data set (2019)	On going
2	2	First report, February 2011	On going

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

DNREC Watershed Assessment

Center for the Inland Bays

## IMPLEMENTATION ACTIONS

### CITY OF NEW CASTLE COASTAL RESILIENCY PROJECT

This project is designed to assist the community of the City of New Castle, Delaware in their efforts to reduce hazard vulnerability that currently exists and that could potentially increase in the future due to the impacts of climate change. The City of New Castle currently experiences a number of coastal related problems including; nuisance flooding of streets and road closures due to flooding; storm damage and erosion of dikes; periodic property flooding; and other coastal hazard impacts.

Before communities can develop effective hazard mitigation strategies, they must first identify their hazard risks and assess their vulnerability to the impacts of those hazards. This project will conduct a community-wide vulnerability assessment with broad community involvement and engagement. This will result in an action plan of prioritized projects designed to make the community more resilient, or at a minimum be prepared to recover, from damages associated with coastal hazards.

#### GEOGRAPHIC LOCATION:

City of New Castle

#### OUTCOME:

The goal of this project is to develop a community-wide action plan that increases the resiliency of the City of New Castle, Delaware to the current and future affects of coastal storms and climate change. The project will develop a proactive plan that outlines the specific vulnerabilities of the community and the best actions to be pursued to address these issues. This will include actions to address current risks as well as future risks associated with climate change, including the potential impacts of sea level rise, increased storm frequencies and intensities, tidegate and dike problems or failures, wetland loss, and other impacts.

#### ACTIVITIES/SCHEDULE:

1. *Data Collection and Synthesis:* DCP has submitted a Request for Qualifications (RFQ) in search of firms that will assist in collecting data on the existing tide gates and dikes. More specifically, the selected firm will:
  - a. Perform dike breach analysis and prepare inundation mapping for selected dikes around the City of New Castle
  - b. Perform tide gate analysis including functionality with anticipated sea level rise.
  - c. Prepare Emergency Action Plans for selected dikes around the City of New Castle.
  - d. Prepare Operation and Maintenance Manuals for dikes and tide gates around the City of New Castle.
  - e. Provide engineering support services to the Department as requested in response to dike-related incidents and emergencies including post-incident tasks such as data collection, review and assessment of structures and facilities, and assisting the Department or City of New Castle with planning, designing, and implementing dike repairs.

In addition, existing information will be analyzed and disseminated to provide a factual context to community members about their current storm flooding risk and vulnerabilities.

2. *Vulnerability Assessment:* Conduct a more detailed vulnerability assessment to be used as a guide for developing mitigation strategies and prioritizing mitigation projects.
3. *Strategy Development:* Utilize the detailed results of the vulnerability assessment to develop a final prioritization of needs and a set of strategies to address these needs.
4. *Action Plan Implementation:* A longer term effort to implement the action plan with short term assistance from DCP.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Data Collection and Synthesis</b>		October 2010	Dike Evaluation and Maintenance Plan preparation in progress
<b>Vulnerability Assessment</b>	-----	Summer 2011	In progress
<b>Strategy Development</b>	-----	Summer 2011	Developing workgroup for implementation planning
<b>Action Plan Implementation</b>	-----	Summer 2011	Not Started

#### AGENCIES INVOLVED:

DNREC Division of Watershed Stewardship

DNREC Division of Fish and Wildlife

Delaware Emergency Management Agency

New Castle County Emergency Management

Federal Emergency Management Agency

Delaware Department of Transportation

UD Sea Grant

City of New Castle

## DEVELOPMENT OF A COASTAL FLOOD MONITORING SYSTEM FOR DELAWARE

In the last two decades, storms such as Hurricanes Katrina and Ike along the Gulf of Mexico and Floyd and Hugo along the Atlantic Coast of the United States have resulted in significant loss of life, injuries and property damages reaching well over 100 billion dollars. Much of the damage associated with these and other tropical and extra-tropical weather systems is associated with severe coastal flooding. The Delaware coastline is extremely vulnerable to such events, examples being the great March 1962 storm and the recent coastal flooding incident of May 12, 2008 which left at least one person dead and many homeless after ocean flood waters destroyed homes, especially along the Delaware Bay Coast of Kent County. The added concern of sea-level rise and its effect on the frequency and intensity of coastal flooding events, further emphasizes the need for a modern, dependable coastal flood monitoring system for Delaware's coastal communities.

This project will develop a real-time coastal flood monitoring and warning system for the coastal communities within Kent County, Delaware. This system will serve as a prototype for similar protection along the entire Delaware coast. We will build on the existing competencies of the Delaware Environmental Observing System (DEOS) and the Delaware Geological Survey (DGS) in the development of this prototype system. The deliverables from this project will directly impact several State agencies including the Delaware Department of Natural Resources and Environmental Control (DNREC), the Delaware Emergency Management Agency (DEMA), the Delaware Department of Transportation (DelDOT) and the Delaware National Estuarine Research Reserve (DNERR). Moreover, the proposed system will have a direct impact upon the safety and well-being of Delaware's coastal communities. The system will allow State constituencies to be informed as to tidal conditions and possible flooding situations up to 120-hours in advance of their occurrence. Moreover, the system will indicate those areas that are most likely to be affected by any tidal flooding (roadways, facilities, homes, etc.) allowing for immediate response by appropriate State and County agencies.

### GEOGRAPHIC LOCATION:

Coastal Kent County Delaware

### OUTCOME:

When complete, DEOS and DGS observation sites will continuously monitor environmental conditions across the Delmarva Peninsula. The DEOS will also ingest forecasted tidal levels, based upon astronomical and meteorological conditions, provided through NOAA. When a forecasted (or real-time) critical tidal level is reached, the DEOS ALERTS system will send a message to all interested State officials warning that a coastal flooding situation is possible, which will prompt them to go to the Coastal Flood Monitoring web page. The web page will contain pertinent real-time and forecasted tidal and meteorological information as well as flood inundation maps for each major coastal community along the Kent County coast. Maps will be produced at appropriate flood levels using the latest LIDAR elevation data. Both paper (for dissemination to State and County agencies) and digital (for inclusion on the Coastal Flood Monitoring web page) maps will be produced.

Development of the system will proceed in tandem with the completion of the coastal monitoring GAP Analysis and the inland flood inundation survey. The GAP Analysis will both inform and be informed by the coastal flood monitoring system development. The survey of high water marks during previous coastal flooding events will be conducted using standard surveying techniques by the Delaware Geological Survey. High water marks will be identified, their history confirmed and

the inundation level recorded. This data will be used in conjunction with observed tide heights at USGS tidal monitoring points to better understand the inland inundation associated with various tidal levels along the coast. The association between tide levels at current coastal monitoring sites and inland flood levels is critical in developing statistical relationships that can be used in the development of a coastal flood model that accurately depicts possible inland flooding given a prediction of tidal anomalies at current monitoring sites.

#### ACTIVITIES/SCHEDULE:

1. *Data Collection & Database Modification:* Perform coastal flood inundation surveys, integration of “forecast” data into DEOS data base structure, initial production of flood inundation maps for coastal communities, modification of DEOS ALERTS system for forecast data.
2. *System Integration, Testing & Implementation:* Completion of flood inundation maps, testing of DEOS ALERTS system with forecasted data, development of Coastal Flood Monitoring web page, development of prototype coastal flood statistical model, implementation of system and final report of the project to be presented to DNREC.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	6	January 2010	Completed
2	9	October 2010	Completed

The website for the Coastal Flood Warning System can be found linked to the DEOS website at: <http://www.deos.udel.edu/index.html>

#### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware, Dept of Geography

Delaware Geological Survey

University of Delaware EPSCOR

## DEVELOPMENT OF A COASTAL RESILIENCY ACTION PLAN FOR BOWERS BEACH

Bowers Beach, Delaware is a small Bayfront community in Kent County located between the St. Jones and the Murderkill River. This small town is home to a small commercial fishing fleet and is a popular place for recreational boaters. Although its location makes it attractive for waterfront living and recreating, its location also makes the Town particularly vulnerable to the effects of coastal storms and sea level rise.

This project is designed to assist the community of Bowers Beach, Delaware in their efforts to reduce coastal hazard vulnerability that currently exists and that could potentially increase in the future due to the impacts of sea level rise. Bowers Beach currently experiences a number of coastal related problems including nuisance flooding of streets, episodic storm damage, coastal erosion, and other coastal hazard impacts.

The goal of this project is to develop a community-wide action plan that increases the resiliency of Bowers Beach, Delaware to the current and future effects of coastal storms and seal level rise. The project will develop a proactive plan that outlines the specific vulnerabilities of the community and the best actions to be pursued to address these issues. This will include actions to address current risks as well as future risks associated with climate change, including the potential impacts of sea level rise, increased storm frequencies and intensities, increased rates of erosion, salt water intrusion, wetland loss, and other impacts.

### GEOGRAPHIC LOCATION:

Town of Bowers Beach, Kent County, Delaware.

### OUTCOME:

The final outcome will be an action plan of prioritized projects designed to make the community more resilient, or at a minimum be prepared to recover, from damages associated with coastal hazards. The Town will also acquire the skills necessary to identify and seek out funding opportunities to finance project implementation.

### ACTIVITIES/SCHEDULE:

1. *Phase I-Data Collection and Synthesis:* This first phase of the project will include the collection, analysis, and dissemination of existing information to provide information to community members about their current storm flooding risk and vulnerabilities.
2. *Phase II-Vulnerability Assessment:* Phase two will include a detailed workshop(s) to gather further information and to conduct a detailed vulnerability assessment to be used as a guide for developing mitigation strategies and prioritizing mitigation projects. A Hazards Characterization workshop was conducted to collect the personal experiences from coastal storm and flooding events from the town residents, as well as to identify their initial concerns relating to these storm events. The information gathered during this workshop will be used by a technical workgroup, comprised of State and County experts in project planning and hazard preparations and town representatives, for development of a formal vulnerability assessment and initial mitigation strategy.

3. *Phase III-Strategy Development:* Phase three will utilize the detailed results of the vulnerability assessment to develop a final prioritization of needs and a set of strategies to address these needs.
4. *Phase IV-Implementation:* This phase will be a longer term effort to implement the action plan. Delaware Coastal Programs will take on an advisory role in assisting the town with procuring funding, project design and tracking.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Phase I</b>	9	Winter 2010	Drainage Study ongoing; project webpage published
<b>Phase II</b>	9	Winter 2010	Hazard Workshop conducted and summary document completed;  Assessment workshop conducted; Assessment workshop evaluation ongoing.
<b>Phase III</b>	9	Winter 2010 Spring 2011	-----
<b>Phase IV</b>	12	Spring 2011	-----

AGENCIES INVOLVED:

Town of Bowers Beach

Division of Watershed Stewardship -Shoreline and Waterway Management Section and Drainage Section

Delaware Emergency Management Agency

Kent County Emergency Management

Federal Emergency Management Agency

Delaware Department of Transportation

UD Sea Grant

## POLICY DEVELOPMENT

### DEVELOPMENT OF A STATEWIDE SEA LEVEL RISE ADAPTATION PLAN

Sea level rise will have economic, social and environmental effects throughout the State of Delaware. Sea level rise increases the height of storm waves, making more areas vulnerable to storm damage and can inundate low lying areas, causing losses to tidal wetlands, habitat, and agricultural areas. Sea level rise also can cause higher water tables and salt water intrusion, interfering with the septic systems, drinking water and irrigation water. These effects have implications for coastal access and recreation, transportation networks, public safety and land use patterns.

To address these issues, the Delaware Coastal Programs will develop a Statewide Adaptation Plan for Sea Level Rise. Using the data and information collected from other parts of the Sea Level Rise Initiative in combination with the expertise of many other agencies, the adaptation plan will recommend policy changes and practices that will ensure that Delaware makes informed policy and investment decisions today to prevent damage and losses to infrastructure, resources and homes tomorrow. Recommendations will be based upon a careful assessment of potential effects to landowners, communities, economies, natural resources and infrastructure using the best available science and technology.

Development of the Sea Level Rise Adaptation Plan will be guided by an Advisory Committee that is comprised of representatives from state agencies, municipal governments, business and development advocacy groups and environmental advocacy groups. Significant opportunities for public involvement will also be integral to the development of the plan.

#### GEOGRAPHIC LOCATION:

This project will be statewide.

#### OUTCOMES:

The final outcome of this project will be the publication of a Statewide Sea Level Rise Adaptation Strategy that will outline recommended policies and management strategies to reduce the State's vulnerability to the impacts of Sea Level Rise.

Additional outcomes will include:

- Proceedings Document: Sea Level Rise Issues Characterization Workshop
- Statewide Assessment of Delaware's Vulnerability to Sea Level Rise
- Proceedings Document: Sea Level Rise Adaptation Strategies Workshop
- Increased awareness of the impacts of Sea Level Rise at the state and local level
- Increased interagency coordination on Sea Level Rise issues
- Public outreach
- Implementation of strategies

#### ACTIVITIES/SCHEDULE:

1. *Initial Issues Characterization Workshop:* One-day workshop to begin discussing and outlining potential impacts of sea level rise in Delaware. This workshop was held in March, 2009.
2. *Formation of Advisory Committee:* Agencies and organizations will be invited to participate in the Sea Level Rise Advisory Committee and monthly meetings will convene.
3. *Vulnerability Assessment:* Advisory Committee and Delaware Coastal Programs staff will conduct a statewide screening assessment of Delaware's potential vulnerability to sea level rise.
4. *Strategy Development:* Recommendations for strategies to reduce Delaware's future vulnerability to sea level rise will be drafted by the Advisory Committee and during a public workshop. These strategies will be refined and made available to the public for comment prior to finalizing the document.
5. *Implementation of Priority Strategies:* Strategies will be ranked by the Advisory Committee. Funding and other resources will be sought to implement priority strategies.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	2	March 2009	Completed
2	2	November 2010	Underway
3	6	February 2011	Underway
4	8	October 2011	Not yet begun
5	**	**	Not yet begun

\*\* Implementation will be an on-going task with no certain end date

#### AGENCIES INVOLVED:

The following agencies and organizations were invited to participate in the Advisory Committee:

Delaware Department of Agriculture

Delaware Department of Health and Social Services

Delaware Department of Natural Resources and Environmental Control

Delaware Department of Transportation

Delaware Department of Safety and Homeland Security

Delaware Economic Development Office

Delaware Farm Bureau  
Delaware Insurance Office  
Delaware League of Women Voters  
Delaware Nature Society  
Delaware Office of Management and Budget  
Delaware Office of the Governor  
Delaware Realtors Association  
Delaware State Chamber of Commerce  
Home Builders Association of Delaware  
The Nature Conservancy, Delaware Chapter  
Positive Growth Alliance  
Tidewater Utilities, Inc.  
University of Delaware College of Earth Ocean and the Environment

## MID-ATLANTIC REGIONAL COUNCIL ON THE OCEANS (MARCO)

In June 2009 the Governors of Delaware, Maryland, New Jersey, New York, and Virginia convened a summit to mark the signing of the *Mid-Atlantic Governors' Agreement on Ocean Conservation* and the establishment of the Mid-Atlantic Regional Council on the Ocean (MARCO). Discussions held at the Governors Summit built on expert knowledge and led to the identification of initial actions that advance each of the Governors' four shared priorities. Under the MARCO umbrella the five states are working together to address the four priority issue areas which include: protection of sensitive and unique offshore habitat areas; support for the sustainable development of offshore renewable energy; prepare the region's coastal communities for the impacts of climate change on ocean and coastal resources; and promote improvements in the region's coastal water quality. MARCO has recently added a fifth priority to address coastal and marine spatial planning (CMSP) in light of the President's Ocean Policy Task Force recommendations to develop a national framework for CMSP. CMSP is seen by MARCO as a means to advance most, if not all, of the four priorities and each state is taking steps to aid in the development, coordination, and integration of coastal and marine spatial plans for the region.

The Governors Agreement also called for MARCO to hold a Stakeholder Workshop on the initial action plan. In December 2009, key state and federal agency representatives along with high-profile leaders of the full range of ocean interests learned from each other, deliberated, and made commitments to advancing MARCO's shared actions on its priority areas. Based on the valuable feedback and dialogue from the stakeholder workshop, MARCO is collaborating with federal partners to implement the priority actions and is drafting an updated action plan. The DCP hosted two two-day MARCO working meetings in May and August 2010 to further the state-federal partnerships and the updated action plan.

More information can be found on the MARCO website: [www.midatlanticocean.org](http://www.midatlanticocean.org).

### GEOGRAPHIC LOCATION:

Mid-Atlantic region, including the states of Delaware, New York, New Jersey, Maryland, and Virginia.

### OUTCOME:

MARCO will result in improved management of Mid-Atlantic coastal and ocean resources. The collaborative effort will improve outcomes by instituting a regional, ecosystem-based approach and will foster a cooperative and constructive relationship among the states. It will also provide leverage for greater federal investment and action on the states' coastal and ocean management priorities.

### ACTIVITIES/SCHEDULE:

1. *Refine action plan and implement recommendations:* The action plan will be refined based upon the results of the December 2009 stakeholder workshop, the Presidents' Ocean Policy Task Force recommendations and National Ocean Policy, and the recent two day workshop with federal representatives held in August 2010. The plan outlines the goals, specific objectives, and initial actions for each of the four priority areas. Each initial action specifies which state will take the lead on it, which objective(s) it advances, and a proposed timeframe or completion date.

2. *Working Meetings:* The DCP will host and/or attend quarterly/triannual MARCO working meetings for both state and federal representatives.
3. *Stakeholder Engagement:* MARCO is in the process of applying for Federal grant funds to help organize and facilitate stakeholder engagement workshop(s).
4. *ELI Policy Review:* The DCP has contracted with the Environmental Law Institute (ELI) to conduct a detailed review and assessment of the laws, policies, and programs related to offshore renewable energy development activities in the Mid-Atlantic states coastal zones and adjacent federal waters. This will focus on Delaware, but also include information from the other five MARCO states. ELI began work in September 2010 and is on schedule to complete by April 2011.
5. *Regional SLR Adaptation:* The DCP is the lead on addressing MARCO's goal of preparing the region for sea level rise impacts on regional infrastructure, coastal habitat, and shoreline management. DCP will guide the development of vulnerability assessments and sea level rise scenarios for the MARCO region and to promote regional information exchange about adaptation across the states.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	12	June 2011	In progress
2	12	October 2011	In progress
3	24	October 2012	Not yet initiated
4	6	March 2011	In progress
5	2	October 2012	In progress

**AGENCIES INVOLVED:**

States of Delaware, New York, New Jersey, Maryland, and Virginia

## SUSTAINABLE COASTAL COMMUNITIES

Most land use decisions in Delaware are made at the local level, yet those making decisions often lack technical expertise and/or planning resources. To address the lack of technical and planning resources, the Delaware Coastal Programs offers grants and technical assistance to local governments, state agencies and not-for-profit organizations for planning, natural resource management and coastal hazard mitigation.

In previous years, this funding and technical assistance has helped communities develop ordinances, incorporate natural resource considerations into comprehensive land use plans, inventory natural resources and restore important coastal habitats. In 2009 and beyond, the grant program will be more focused towards assisting community planning for reducing impacts resulting from coastal hazards and assessing vulnerabilities and risks to plan for future impacts of sea level rise.

### GEOGRAPHIC LOCATION:

Grants will be available Statewide, through a competitive RFP process.

### OUTCOME:

This program will result in improved management of Delaware's coastal resources through incorporation of coastal hazard and natural resource considerations into local comprehensive plans. This includes coastal storm resiliency planning, development of coastal management ordinances to reduce impacts, and educational outreach for Delaware's local governments.

The DCP anticipates funding and assisting with 3 – 5 projects per year.

### ACTIVITIES/SCHEDULE:

1. *Release RFP and Award Grants:* The funding will be announced through a “Request for Proposals.” Grant proposals received will be ranked by a committee of resource experts and successful grant applicants will be notified.
2. *Grants Management:* DCP staff will negotiate contracts for each grant recipient and will provide technical assistance until the project has been completed.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	4	December 2010	Underway
2	14	March 2012	Not yet underway

### AGENCIES INVOLVED:

Delaware Coastal Programs

## COMMUNICATION, TRAINING AND PUBLIC INVOLVEMENT

### COMPREHENSIVE MARKETING & OUTREACH STRATEGY FOR SEA LEVEL RISE

In order to effectively communicate to the public and decision maker audiences regarding sea level rise issues, the Delaware Coastal Programs (DCP) established a Sea Level Rise Outreach Strategy Committee comprised of educators, marketers, and communication specialists from the Delaware National Estuarine Research Reserve, Delaware Sea Grant, the Partnership for the Delaware Estuary, DNREC – Public Affairs, DNREC – Shoreline and Waterway Section, in addition to staff from DCP to develop a comprehensive sea level rise marketing and outreach strategy. The strategy provides a clear, coordinated message with information and materials developed and disseminated by all of the organizations of the Committee including Delaware Coastal Programs, Delaware National Estuarine Research Reserve.

As part of the development of this comprehensive strategy, a statewide survey to gauge public knowledge and opinions on sea level rise and its impacts on Delaware was completed in the spring of 2010. This survey provides information about Delaware residents' awareness and understanding of key issues regarding climate change and sea level rise; determine their perception of its overall effect on the economy and ecology of the state; and explore public opinion regarding long range planning for sea level rise loss and damage prevention. Using the results of this survey, as well as other studies and reports focused on improving communications on sea level rise and climate change, a comprehensive marketing and outreach strategy has been drafted to enhance the public and coastal stakeholders' awareness and response to sea level rise.

The strategy considers a variety of audiences (such as local, county, and state government officials, local and regional planners, economic development representatives, agriculture representatives, university researchers, educators, and property owners) and includes workshops, seminars, brochures, factsheets, public service announcements, media buys, website development and/or outreach displays.

#### GEOGRAPHIC LOCATION:

Statewide

#### OUTCOME:

A comprehensive marketing and outreach strategy and an implementation/work plan have been drafted.

#### ACTIVITIES/SCHEDULE:

1. *Strategy Development:* An inventory of existing Sea Level Rise marketing and outreach programs will be completed and will be analyzed along with results of the Sea Level Rise Attitudes and Perception Survey. This analysis will then be interpreted to design a targeted Marketing and Outreach program.
2. *Strategy Implementation:* Activities listed in the strategy will be implemented.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	4	Fall 2010	Draft Completed
<b>2</b>	Ongoing as needed	-	Underway

AGENCIES INVOLVED:

DNREC

Delaware Coastal Programs

Division of Watershed Stewardship/Shoreline & Waterway Management

Public Affairs

Delaware Sea Grant

Partnership for the Delaware Estuary

Responsive Management

## SEA LEVEL RISE INTERNET MAP VIEWER

Land-use decisions in Delaware are primarily made at the local level yet, often these smaller towns lack the GIS infrastructure that would allow large scale planning efforts, particularly those related to coastal hazards. Delaware Coastal Programs has made significant investment in GIS data, personnel, and hardware over the years. Transferring the benefits of this investment to community decision makers is vital to the success of these planning efforts.

As part of DCP's efforts assisting local governments with Coastal Hazard and Community Resilience Planning, data will be created and shared with the local decision makers and the community. Internet based mapping applications can be a useful tool to affect this sharing. Most local governments and citizens have access to basic internet browsers either at home or in public libraries. Online mapping tools such as Google Maps and Virtual Earth provide free, lightweight mapping tools that members of the public can use to participate in planning efforts. More robust applications, such as ArcGIS Server and Google Earth, allow for more complex views of Community Resiliency information while keeping costs at a minimum (i.e. free to end user). The choice of tool used will depend on the needs of the user and the ability of the tool to present the data.

DCP has utilized ArcGIS Server to produce and distribute Statewide Sea Level Rise Inundation maps for these planning efforts. KML versions of the data are available, however, the datasets are too large to be conveniently accessed on slower internet connections. ArcGIS Server provides both a freely accessible viewer for the general public and advanced access for GIS users to a map service.

### GEOGRAPHIC LOCATION:

Maps of DNEC's Sea Level Rise Inundation Scenarios are available statewide. Distribution of more localized data will initially focus on individual communities undergoing resiliency planning (i.e. Town of Bowers and City of New Castle).

### OUTCOME:

Website(s) providing citizen access to Community Resilience Planning Maps.

<http://www.dnrec.delaware.gov/Pages/SLRMaps.aspx>

### ACTIVITIES/SCHEDULE:

1. *Software needs assessment and acquisition:* Evaluate capabilities of various software to provide mapping data to public through open GIS browsers. Acquire selected software.
2. *Data List:* Develop and initial list of data to be distributed to community members.
3. *Data Conversion:* Convert selected data and maps for distribution.
4. *Website creation:* Establish a new set of pages within DCP's Sea Level Rise web section for distribution of mapping information.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	1 month		Complete
<b>2</b>	1 month		Complete
<b>3</b>	1 month		Complete
<b>4</b>	1 month		Complete

AGENCIES INVOLVED:

Delaware Coastal Programs

DNREC – Office of Information Technology

## STATEWIDE SURVEY TO GAUGE PUBLIC KNOWLEDGE AND OPINIONS ON SEA LEVEL RISE AND ITS IMPACT IN DELAWARE

In order to effectively plan and target sea level rise outreach and technical assistance, it is important to understand the public perception of sea level rise. However, there is currently no statewide information available regarding the level of knowledge Delawareans possess regarding sea level rise and its future impacts; nor whether Delawareans are motivated to change their behaviors to reduce their risk to impacts associated with sea level rise.

In order to address this need, the Delaware Coastal Programs, in cooperation with The Nature Conservancy and with contractual assistance from Responsive Management Inc. conducted a statewide telephone survey during the fall 2009. The survey was designed to be statistically significant and to assess Delaware residents' awareness and understanding of key issues regarding climate change and sea level rise; to determine their perception of its overall effect on the economy and ecology of the state; and to explore public opinion regarding long range planning for sea level rise loss and damage prevention.

The survey was completed in January 2010 and is available for download online:  
<http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/SLRSurveyReport.pdf>

### GEOGRAPHIC LOCATION:

The telephone survey was conducted statewide.

### OUTCOME:

The survey resulted in a written report that includes a summary of results; discussion of data analysis and statistical procedures, a tabular data report, survey graphs and tables, frequency distributions and cross-tabulations. The report has since been used to help in the development of an outreach and marketing strategy, and to guide the content of other outreach and educational products.

### ACTIVITIES/SCHEDULE:

1. *Develop survey instrument:* In cooperation with other interested agencies and Responsive Management, design and test the survey.
2. *Conduct Telephone Survey:* Responsive Management will conduct the phone survey using random dialing.
3. *Analyze Results:* Responsive Management will analyze the results of the survey with appropriate statistical tests.
4. *Prepare Report:* Responsive Management will prepare a final report that provides an executive summary, methodology, data and appropriate charts and graphs.
5. *Distribute and Explain Report:* Final report will be made available via the web and hard copy. Workshops will be held in cooperation with the Nature Conservancy and Responsive Management to explain the results of the survey.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	2	July 2009	Complete
<b>2</b>	2	November 2009	Complete
<b>3</b>	2	December 2009	Complete
<b>4</b>	1	January 2010	Complete
<b>5</b>	6	March 2010	Complete

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

The Nature Conservancy

Responsive Management

PREPARING FOR SEA LEVEL RISE  
DEVELOPMENT OF A SEA LEVEL RISE INITIATIVE

Sea Level Rise Initiative  
Project Compendium  
October 2010



*Photo by: Delaware Shoreline and Waterway Management Section*

*A Compendium of Delaware Coastal Programs' Projects that Address  
Sea Level Rise*



Delaware Coastal Programs

(302) 739-9283



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## THE SEA LEVEL RISE INITIATIVE

In recognition of the importance of the coast to the Nation's commerce, energy development and natural resource protection, the Coastal Zone Act of 1972 was enacted to assist States manage these conflicting uses of coastal areas. At that time, in addition to directing State Coastal Zone Management Programs to address issues of pollution, development, navigation and energy development, the Coastal Zone Act also directed States to prepare for sea level rise.

In recent years, improved climatic and ocean observation systems have made it possible for scientists to better assess the potential for sea level rise and make predictions for the future. These predictions have shown that coastal areas, particularly in the Mid-Atlantic states, will likely see an increased rate of sea level rise. The U.S. Climate Change Science Program's (CCSP) 2009 document, "Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic" recommends that states should prepare for sea level to rise by at least one meter (39 inches) by 2100; the current rate of sea level rise measured by a tide gauge in Lewes Delaware is 13 inches per 100 years. The CCSP prediction is in close agreement with many other predictions by Federal, State and Global agencies and represents a three-fold increase in the historic rate of sea level rise.

This level of sea level rise will have economic, social and environmental effects throughout the State of Delaware. Sea level rise will inundate low lying areas, causing significant losses to tidal wetlands and wildlife habitat. As the high tide line encroaches landward, some important agricultural areas may no longer be suitable for tillage. Sea level rise also can cause higher water tables and salt water intrusion, interfering with the septic systems, drinking water and irrigation water. Most importantly for many coastal communities, sea level rise can increase the effects of storm surge and waves, allowing flooding to occur in areas that may have never previously been susceptible to flooding from storms. All of these potential effects from sea level rise also have implications for coastal access and recreation, transportation networks, public safety and land use patterns.

To help assess, prepare for and minimize the potential impacts of sea level rise, the Delaware Coastal Programs Section of the Delaware Department of Natural Resources and Environmental Control is leading a multi-year Sea Level Rise Initiative. The goal of the Sea Level Rise Initiative is to reduce Delaware's future vulnerability to the effects of sea level rise. This will be accomplished by:

- Providing scientific and technical support for decision-making
- Implementing on-the-ground project in partnership with stakeholders
- Providing educational and outreach opportunities for stakeholders and the public
- Improving existing policies and management practices and/or developing new policies and management practices where necessary

As part of the goal of providing scientific and technical support for decision-making, Delaware Coastal Programs scientists have partnered with the National Wildlife Refuge System, the University of Delaware, local Estuary Programs and other state agencies to fill gaps in our knowledge about coastal storms, tide levels and marsh sediment accretion. This data and information will be used for policy development; communication of this new information is a component of the outreach strategy.

As part of the goal of implementing on the ground projects, Delaware Coastal Programs staff have partnered with the City of New Castle and the Town of Bowers Beach to help them improve their

preparedness for coastal storms and future sea level rise. Related to this effort, and using high resolution elevation data, a real time flood monitoring system is being developed that will greatly improve flood response in coastal communities.

Public involvement and outreach is a critical component of preparing for sea level rise. All of the tools and data developed during the Sea Level Rise initiative will be communicated to the public through websites, presentations, public events, articles and decision-maker workshops. This is detailed in a comprehensive outreach strategy for sea level rise, developed in partnership with the DNREC Watershed Stewardship Division, the Delaware Estuary Program and Delaware Sea Grant.

These projects, along with others described in this document, have been initiated under the Sea Level Rise Initiative to help to build partnerships and capacity, increase resiliency, increase public knowledge of and support for actions to reduce our vulnerability and make decisions based upon the best available science. The Sea Level Rise Initiative is designed to be iterative and will grow and change as new data, outreach and policy needs are identified.

## PURPOSE OF COMPENDIUM OF SEA LEVEL RISE INITIATIVE PROJECTS

The purpose of the Sea Level Rise Initiative Compendium of Projects is to provide an at-a-glance inventory of the projects and initiatives are being conducted as part of the Delaware Coastal Programs' Sea Level Rise Initiative. It is intended to help increase collaboration between agencies, reduce redundancy and overlap in projects relating to sea level rise and to relay information about new (or soon to be available) data, information and tools.

Projects conducted without the assistance or involvement of the Delaware Coastal Programs are not currently reflected in this document. However, there are many other agencies whose work will be essential to preparing for sea level rise and coastal inundation. The Delaware Coastal Programs may in the future consider expanding the scope of this document to include other agencies' work.

Because the projects listed in this document are likely to evolve over time, it is our intent to update this document on a routine basis so that our partner agencies can be kept up to date on sea level rise activities. The most current version of the document will be posted on the Delaware Coastal Programs' sea level rise website.

## FOR MORE INFORMATION

For more information about projects contained within the Sea Level Rise Initiative Compendium, please contact us at (302) 739-9283 or see our website:

<http://www.swc.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx>

## SCIENTIFIC AND TECHNICAL SUPPORT

### BOMBAY HOOK HYDROLOGY/SEDIMENT MOVEMENT STUDY

Coastal areas and natural resources are particularly vulnerable to climate change, especially with respect to accelerated sea level rise, shoreline erosion, increased storm frequency and intensity, changes in rainfall, and related flooding among other potential impacts. Investigation of such impacts, specifically marsh depletion and increased mudflats at Bombay Hook, will be conducted to determine patterns of sediment flux in or out of the depleted marsh area.

Data collection will involve conducting river transects within the Leipsic River using the Acoustic Doppler Current Profiler (ADCP) and associated software to collect and process tide and current data. Water quality will also be monitored, specifically total sediment solids (TSS) to aid in determining sediment fluxes in or out of the depleted marsh area.

#### GEOGRAPHIC LOCATION:

Bombay Hook National Wildlife Refuge.

#### OUTCOME:

This study will result in a written report that includes a summary of results; discussion of data analysis and statistical procedures. Results will be used to predict future changes in marsh depletion and to help determine marsh management techniques to counteract these impacts affecting the tidal marshes at Bombay Hook.

#### ACTIVITIES/SCHEDULE:

1. *Installation of monitoring equipment:* Install 5 water level recorders and 1 Acoustic Doppler Current Profiler.
2. *Perform cross-section current profiles and collect data:* Perform a series of cross-section current profiles at various locations over varying tidal stages and collect water level and ADCP data.
3. *Analyze data and write report:* Data collected to date will be analyzed and interpreted leading to an interim report. This report can be used as a basis for a more detailed study and support future modeling efforts in the Refuge

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	1	May 2009	Completed
<b>2</b>	NA	Ongoing	Ongoing
<b>3</b>	3	March 2011	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS

## COASTAL IMPOUNDMENT ACCRETION RATE STUDY

As an accelerated rate of relative sea-level rise further stresses impounded marshes, there is a greater need to evaluate the long-term sustainability and utility of impoundments in Delaware. In order to do this, baseline data regarding historic sedimentation rates is needed.

Baseline data sets of long-term sedimentation rates in impounded and natural wetlands can be utilized to evaluate the impounded wetlands' ability to achieve optimal habitat benefit under different management strategies and under different sea level rise scenarios

Long-term sedimentation rates over the past 100 and 50 years can be calculated by collecting radioisotopic cores from wetland areas and analyzing them for  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$ . All core sites and the adjacent wetland will be surveyed to tie all data to the tidal datum (NAVD 88). Correlating long-term wetland sedimentation rates to current wetland elevation will enable a detailed analysis of the potential sedimentation deficits that exist within the impoundments, as compared to the reference wetlands. The elevation and sedimentation gradients between the reference and impounded wetlands can be used to calculate potential future elevation trajectories under different sea-level rise and management scenarios.

### GEOGRAPHIC LOCATION:

Monitoring sites were chosen within impounded and reference (natural marsh) sites throughout the State based upon a wetland area change analysis (using a time-series of available imagery), and basins that have been identified as needing detailed study to aid in their management to optimize the future available habitat. Sites that will be studied include: marshes along the Delaware River near New Castle; Ted Harvey Wildlife Area; St. Augustine Wildlife Area; and Primehook National Wildlife Refuge.

### OUTCOME:

When complete, this study will provide information to coastal managers regarding marsh susceptibility to sea level rise under different marsh management scenarios and under different sea level rise scenarios. A long-term comparison of the wetland elevation and sedimentation conditions between the impounded marsh and the "natural" marsh will enable a detailed analysis and comparison of the potential long-term growth conditions and highlight the potential implications for impoundment management that could affect the sustainability of the interior wetlands. This information will allow marsh managers to understand the potential outcomes of sea level rise and adapt their management techniques.

### ACTIVITIES/SCHEDULE:

1. *Initial Impoundment Core Collection:* Radioisotopic cores will be collected from selected marshes. All core sites and adjacent wetlands will be surveyed. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis is scheduled to be complete by December 2009.
2. *New Castle Impoundment Core Collection:* Radioisotopic cores will be collected from 3 impoundments and 2 reference marshes along the Delaware River adjacent to the City of New Castle. All core sites and adjacent wetlands will be surveyed after collection. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis is expected to be complete by December 2010.

3. *Kent County and Lower New Castle County Impoundment Core Collection:* Radioisotopic cores will be collected from Ted Harvey Wildlife Area, St. Augustine Wildlife Area, and Primehook National Wildlife Refuge. The Ted Harvey and St. Augustine sites were selected to expand the scope of the impoundment investigation to include sites along the entire Bay and River coast. All core sites and adjacent wetlands will be surveyed after collection. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis by UD is expected to be completed by December 2011.
4. *Gap Analysis of Delaware Coast:* A gap analysis of the Delaware River and Bay Coast Impoundments and reference marshes will be conducted to identify areas where additional cores should be collected and analyzed. The previously analyzed cores will be examined to evaluate the spatial and temporal variability within the study areas and evaluate the need for additional coring sites. A total of 18 cores will be collected to fill in the identified data gaps and areas of high spatial sedimentation rate variability.

<u>Activity</u>	<u># months req'd for completion</u>	<u>Activity Start Date</u>	<u>Estimated DCP Completion Date</u>	<u>Estimated Laboratory Completion</u>	<u>Status</u>
1	5	November 2008	March 2009	April 2010	In Progress
2	8 - 10	April 2009	November 2009	December 2010	In progress
3	6	December 2009	May 2010	December 2011	Pending
4	8	May 2010	January 2011	December 2012	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

UD College of Earth, Ocean and Environment

Primehook National Wildlife Refuge (USFWS)

DNREC Division of Fish and Wildlife

## COASTAL MONITORING GAP ANALYSIS

In the last two decades, storms such as Hurricanes Katrina and Ike along the Gulf of Mexico and Floyd and Hugo along the Atlantic Coast of the United States have resulted in significant loss of life, injuries and property damages reaching well over 100 billion dollars. Much of the damage associated with these and other tropical and extra-tropical weather systems is associated with severe coastal flooding. The Delaware coastline is extremely vulnerable to such events, examples being the great March, 1962 storm and the recent coastal flooding incident of May 12, 2008.

As part of a cooperative effort between the University of Delaware and several Delaware State Agencies to better monitor conditions along the Delaware coastline and to provide advance warning of impending coastal flooding events, we propose the completion of a GAP Analysis of pertinent coastal data needs and a comprehensive survey of inland inundation levels during previous coastal flooding events. The GAP Analysis will define the present state of coastal data collection efforts across the state, an “optimum” data collection network and the gap between them, indicating those data that need to be added to the current network. A survey of high water marks from previous coastal flooding events will be used to create a “baseline” data set to aid in understanding the relationships between water levels at tidal monitoring points and inland locations. In this research, an exhaustive inventory of real-time and archived coastal data will be conducted. This inventory will include meteorological, tidal, buoy, water quality and inundation data sources, along with ancillary sources of coastal information (i.e. research publications, modeling work, etc.).

### GEOGRAPHIC LOCATION:

Coastal Delaware.

### OUTCOME:

The final outcome/product will be a report that makes recommendations as to the type of data needed to reach an “optimum” coastal monitoring network, and the spatial placement and temporal resolution of additional sensors that may need to be deployed to reach the optimum configuration. The report is available at:

[http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Gap\\_Analysis\\_Final\\_Report\\_032910.pdf](http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Gap_Analysis_Final_Report_032910.pdf) or <http://www.deos.udel.edu/delawaregap/index.html>

### ACTIVITIES/SCHEDULE:

1. *GAP Analysis Report:* University of Delaware will conduct the analysis and develop a report that makes recommendations as to the type of data needed to reach an “optimum” coastal monitoring network.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	9	March 2010	Completed

### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware

## COASTAL STORM HISTORY

Several coastal communities in Delaware currently experience storm damage, coastal erosion, and other coastal hazard impacts. In efforts to reduce hazard vulnerability that currently exists and that could potentially increase in the future due to climate change impacts, the Delaware Coastal Programs, along with the University of Delaware are compiling data on historical storms, nor'easters, subtropical storms or hurricanes that may have impacted Delaware's coasts in the past.

This data was previously compiled by the University of Delaware for years up through 1974 and a written report is available. This project will focus on updating the storm data from 1974 to 2009.

### GEOGRAPHIC LOCATION:

Coast of Delaware.

### OUTCOME:

Compendium of historical storm data categorized according to the type of storm, physical characteristics and impacts on coastal communities and natural resources. This can perhaps be used to derive specific scenarios to be modeled for the purpose of future adaptation and preparedness. It will also help to identify where outside expertise should be brought in to provide additional technical assistance for resiliency assessment, planning and implementing. Depending on the detail of the data collected, there may be some insight for prediction of the next potential storm, nor'easter or hurricane and the impacts of such events.

### ACTIVITIES/SCHEDULE:

1. *Storm data collection:* Through analysis of historic data sets and communication with local and state officials and the public, historic storm information will be compiled.
2. *Development of Report:* A compilation report will be developed and distributed. The report will include storm data from 1974 to present including all pertinent data.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Contract signed</b>	n/a	Feb 2010	Completed
<b>1</b>	12	Sept 2010	Completed
<b>2</b>	6	March 2011	Pending

### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware

## DEVELOPMENT OF COASTAL INUNDATION MAPS

Sea Level Rise inundation maps are necessary to determine areas and extent of coastal vulnerability to sea level rise, and will be a key component guiding the development of a Statewide Sea Level Rise Adaptation Plan. While it is relatively straight forward to overlay elevated sea level changes onto existing digital elevation models (DEMs), certain factors must be considered. Primarily, mean tide levels vary along the Delaware Bay Coast and any maps developed must take this into consideration. Secondly, solely using sea level rise will not give a true perspective of inundation, since the major concern will be the flooding from coastal storm surges.

To develop these maps (GIS Layers) a statistical evaluation from the existing 2 long-term NOAA tide level datasets of Lewes (Breakwater Harbor) and Delaware City (Reedy Point) will be performed to establish storm surge elevations above Mean Higher High Water (MHHW) for selected return periods (i.e. 10, 25 50, 100-year return periods). Once these are calculated, the current MHHW levels along the length of the coast will be determined using the NOAA VDatum software. These two datasets will be combined to establish the appropriate elevations to use for coastal inundation. After the Delaware Bay coast is completed, a similar effort will be performed for the Inland Bays and Atlantic Coast.

### GEOGRAPHIC LOCATION:

Coastal Delaware

### OUTCOME:

The final outcome/product will be a series of maps in GIS format that will be based on the bare earth LIDAR data. Several scenarios will be developed using on current sea level rise, predicted average sea level rise and predicted maximum sea level rise for the years 2050 and 2100. Estimates of storm surge added to the predicted elevations will also be provided. These surges will be based on historic data and statistical analysis.

### ACTIVITIES/SCHEDULE:

1. *Statistical Analysis of existing tide data:* Based on existing data for Lewes and Delaware City, develop expected storm surge levels for certain return periods.
2. *Determine MHHW for Bay Coast:* Using VDatum, determine MHHW along Delaware Bay coastline corrected to NAVD88
3. *Develop Inundation Maps for Delaware Bay Coast:* Combining the two developed datasets, produce GIS maps for different seal level and storm surge scenarios
4. *Inland Bays and Atlantic Coast Maps:* Repeat 1-3 for Inland Bays and Atlantic Coast.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	2	September, 2009	Completed
2	<1	October, 2009	Completed
3	2	December, 2009	Completed
4	1	January, 2010	Completed

**It is anticipated that all inundation maps will be frequently updated as new information on sea level rise becomes available.**

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

## DIGITAL COAST

The Digital Coast is a nationwide initiative that is designed to ensure the wise use and management of coastal resources by providing coastal managers with data, training, tools and examples to assist them with emerging and priority coastal issues. The partner network identifies Digital Coast priorities and then works together to address coastal issues.

Currently, the Digital Coast partnership is focused on providing data, tools and examples to coastal managers regarding coastal inundation and sea level rise. Projects to address other coastal issues (i.e., marine spatial planning, conservation) will be developed in the future.

One of the goals behind the creation of the Digital Coast was to unify groups that might not otherwise work together and build a strong collaboration of coastal professionals intent on addressing coastal conservation needs. The Digital Coast Partnership Group is currently comprised of representatives from the Association of State Floodplain Managers, the Coastal States Organization, the National Association of Counties, the National States Geographic Information Council, The Nature Conservancy, and the NOAA Coastal Services Center. Delaware Coastal Programs staff has actively served as part of the Coastal States Organization representatives on this project. The National Oceanic and Atmospheric Administration's

(NOAA) Coastal Services Center is the lead organization for Digital Coast efforts.

### OUTCOME:

In the fall of 2009, the Coastal Inundation Toolkit, was released. The toolkit was being developed by the Digital Coast Partnership Group to help communities understand and address coastal inundation issues. Website components include:

- Understand – Learn about inundation basics and common hazard concepts
- Identify – Download the county-specific charts and graphs that tell your story
- Map – Use the steps provided to discover and map areas of potential impact
- Assess – Use inundation maps to assess community risk, vulnerability, and resilience
- Inform – Use risk communication strategies to illicit change
- Discover – See how other communities are addressing this issue

This tool is expected to be of enormous value as a resource tool for the many groups concerned with and working to address coastal flooding and Sea Level Rise issues in Delaware.

Current and future Modules of Digital Coast resources are available at:

<http://www.csc.noaa.gov/digitalcoast/>

## HYDROLOGIC MONITORING OF THE KITTS HUMMOCK AREA

To properly understand the relationships between the Delaware Bay, interior marsh water levels, ponds, impoundments and the drainage ditch network around Kitts Hummock, a comprehensive water level monitoring program will be established. Establishing a water level monitoring network at key locations will aid in the understating the interrelationships between the water bodies and the influence of the drainage network in the community on these water bodies. This baseline monitoring is one of the prerequisite needs for conducting any defensible modeling and evaluation of the effectiveness of any proposed drainage improvements to the Kitts Hummock area. Additional needs prior to modeling include validation of marsh elevations, detailed documentation and assessment of previous storms, and engineering designs of proposed alterations

This baseline network will use a total of 8 Inset HOBO water level recorders in conjunction with the USGS Tide gauge located approximately 5 kilometers south at Bowers Beach and other currently monitored parameters. Two water level recorders will be placed on the north and south sides of Kitts Hummock Road in the primary N/S drainage ditch approximately 250 meters inland from the Delaware Bay. An additional three water level recorders will be used to examine the effects of marsh water elevation and the northern impoundment of the Logan Lane Tract of the Ted Harvey Conservation Area on the open water area of a private property and the South Bay Drive drainage ditch. The final two water level recorders will be installed in open water areas of the marsh northeast of the community of Kitts Hummock to estimate the tidal backwater effects north of Kitts Hummock Road. A final recorder will be housed at the Delaware National Estuarine Research Reserve (DNERR) to measure barometric pressure changes which will be used to atmospherically correct the readings of the water level recorders. The recorders will be surveyed to an accuracy of  $\pm 2$  cm vertical, and maintained and downloaded monthly by staff from the DNERR.

### GEOGRAPHIC LOCATION:

This project encompasses the area surrounding Kitts Hummock, Kent County, DE, including the private marsh lands north and south of the community and the DNREC/DFW Logan Lane Tract of the Ted Harvey Conservation Area.

### OUTCOME:

Once sufficient data has been collected, which includes a minimum of 3 months of data and at least 3 significant storm events, the data will be compiled. Data on rainfall and wave height, period and direction, currently being monitored by the DNERR, will be incorporated into the data set and then the dataset will be analyzed. This analysis will include examining the Bay tide effects on marsh water/drainage ditch elevations; relationships of surrounding water levels on the Thompson open water area; probable pathways of tide related flooding; and a qualitative evaluation of the expected effectiveness of drainage ditches in the area during different tidal cycles/storm events.

### ACTIVITIES/SCHEDULE:

1. *Data Collection:* Install data recorders, survey locations and collect data.
2. *Data Analysis:* Analyze data, run computer simulations, develop qualitative evaluation of storm event drainage scenarios.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	3-5	October 2009	Complete
<b>2</b>	3	December 2009	Complete

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

DNREC Drainage and Stormwater Section

DNREC District Operations

## MARSH LOSS ANALYSIS (INTERIOR OPEN WATER CREATION)

Staff from Bombay Hook NWR contacted the Delaware Coastal Programs for assistance with their 5-year Biologic Review of the refuge. Refuge staff felt that DCP's experience with GIS analysis could help them answer some questions they had about the changing habitat of the refuge. Coastal change, rising sea levels, erosion and land subsidence are increasingly tough issues facing coastal managers, engineers, and planners charged with developing and protecting coastal habitats and communities in vulnerable coastal zones. Understanding these threats depends on early detection, and solutions will require vigorous public debate over engineering solutions vs. strategic retreat. The drastic changes at Bombay Hook National Wildlife Refuge (NWR) may be a harbinger of coast-wide habitat changes in the future.

The coastal areas of Bombay Hook NWR have historically been subjected to significant erosion. Historical shorelines from as far back as 1842 paint a much different picture than exists today. Shores that face the East and Southeast take the worst damage. These areas have the longest fetch allowing the winds to add more power to the waves that break on these shores. For the period 1937-2002, roughly 1700 ft. of erosion occurred along the southern shoreline of Bombay Hook (26 ft/yr). This habitat loss is now coupled with increasing amounts of open water creation in the interior marsh.

Aerial photos from 1979, 1992, and 2002 were examined for expansion of open water areas in the interior marsh. Photos were viewed on a geographic information system and areas of open water were outlined. Results showed that, over the years, open water areas were growing larger and combining together. What had been a mosaic of small areas of open water mixed in vegetated marsh are becoming large tracts of open water with vegetation around the edges. This Study revealed that since 1979, the Refuge has lost a total of 12% of its wetland area; 10% attributed to the creation of interior, open water areas.

No single, direct cause for the wetland loss has yet been identified. Some potential causes including sea level rise, marsh/land subsidence, and snow goose grazing are being looked into. These effects are inter-related and tend to work together to make matters worse. Currently DCP and others are using sediment elevation tables to explore subsidence and sedimentation in regional marshes. It is hoped that if a cause(s) can be determined, adjustments in marsh management can be made to stem the loss of interior area.

This project will investigate the expansion of open water areas in four additional areas throughout the state: the Thousand Acre Marsh region; Blackbird Creek; Milford Neck and Primehook National Wildlife Refuge. For each area, open water areas will be digitized using ArcGIS from historic aerial photographs to determine extent of open water areas over time.

### GEOGRAPHIC LOCATION:

DCP is now expanding the study to other similar marsh areas around the State: 1000 Acre Marsh, Blackbird Creek, Milford Neck Wildlife Area and surrounding private conservation lands; and Prime Hook NWR with nearby areas in Broadkill Beach.

#### OUTCOME:

This project will result in GIS maps of marsh loss over time for the study areas.

It is also hoped that this information can be combined with results from other studies and may shed light on the causes of the wetland loss. This combination of information is expected to lead to management changes that can limit further loss and possibly aid recovery of the marshes.

#### ACTIVITIES/SCHEDULE:

1. *Digitize open water areas:* Bombay Hook.
2. *Digitize open water areas:* 1000 Acre Marsh.
3. *Digitize open water areas:* Blackbird Creek.
4. *Digitize open water areas:* Milford Neck.
5. *Digitize open water areas:* Prime Hook.

Activity	# months req'd for completion	Estimated Completion Date	Status
1.			Complete
2.			Complete
3.			Complete
4.			Complete
5.			Complete

#### AGENCIES INVOLVED:

Delaware Coastal Programs

## MARSH VULNERABILITY INDEX

An index is needed to allow assessment of the long-term viability of Delaware's marshes under differing sea level rise scenarios and to target areas for conservation, restoration and monitoring. The Tidal Marsh Vulnerability Index will be based upon the positive correlation between mean tidal range and elevational growth range of tidal wetland plant species. Biomass sampling, taken from the Mid-Atlantic Wetland Rapid Assessment Method (MidTRAM), will also be incorporated into the Marsh Vulnerability Index to assess marsh health. Once developed, the Sea Level Rise Index for Tidal Marshes tool could be transferred to other states and used for regional comparisons and regional planning.

The Tidal Marsh Vulnerability Index will classify marshes as healthy, degrading or severely degrading. These classifications will be utilized to select areas to conduct detailed sediment accretion rate and other monitoring. Degraded and severely threatened marshes are known to have lower elevations, relative to the tidal prism, and are more prone to catastrophic losses due to sea-level rise and storm events. Understanding the current and historic sedimentation accretion rates of these marshes can help to better predict the longevity and the sediment deficits of these areas and possible management practices that might be implemented to prevent marsh elevation losses (i.e. thin layer application of sediment, vegetation plantings, etc.).

The Tidal Marsh Vulnerability Index, in conjugation with time-series analysis of aerial imagery, will be essential for evaluating wetland vulnerability on a watershed or statewide basis, while enabling the strategic placement of monitoring resources to enhance our efforts to understand the future evolution potential of Delaware's tidal wetlands. All field based monitoring and sampling efforts can be initiated and implemented to evaluate the most severely threatened marsh areas first; the monitoring can then be expanded to encompass other marsh regions as resources become available. Marsh Vulnerability Index classification optimizes the monitoring efforts and resources to the highest levels possible, so the broadest extent of Delaware's tidal wetlands may be evaluate and managed.

### GEOGRAPHIC LOCATION:

Phase I & III will occur in the two components of the Delaware National Estuarine Research Reserve, and the National Estuary Program, Center for the Inland Bays. Phase II & IV will occur in tidal marshes along the Delaware Bay Coast and inland bays.

### OUTCOME:

Phase I will develop a marsh vulnerability index for *Spartina alterniflora* at three test sites located within the Delaware National Estuarine Research Reserve and the National Estuary Program's Center for the Inland Bays. These three target sites encompass all three counties and three different salinity regimes. This phase will use GIS data, aerial photos, LiDAR data and the Statewide Wetland Mapping Program data along with field validation to develop a *Spartina alterniflora* tidal growth range. These site specific values will be compared with the other regions and values the literature to determine if a Statewide or regional Marsh Vulnerability Index can be developed for

*Spartina alterniflora* marshes. Individual marsh polygon elevations will then be compared with the Marsh Vulnerability Index to estimate the sustainability of that particular marsh.

Phase II will develop a statewide Marsh Vulnerability Index for *Spartina alterniflora* marshes. Contiguous areas of *Spartina alterniflora* will be identified using SWMP data and ArcGIS polygons will be created. Marsh elevation and tidal ranges and mean tide elevations will be determined from the LiDAR dataset and/or additional on the ground sampling. Based on the maximum/minimum elevations derived from the Arc/GIS analysis a refined *Spartina alterniflora* tidal growth range will be developed. The *Spartina alterniflora* marshes throughout the State will then be classified using the Marsh Vulnerability Index. The outcome of Phase II is contingent upon Phase I and a positive index created for *Spartina alterniflora*.

Phase III will develop a marsh vulnerability index for other vegetation types within the same three test sites. Indicator species will be identified that are typically found in other areas of coastal Delaware. These species can be homogeneous communities (species specific index) or common heterogeneous communities (composite index). Based on the maximum/minimum elevations derived from the Arc/GIS analysis, a site specific indicator species composite tidal growth range will be developed. These site specific values will be compared with the other regions to determine if a Statewide or regional composite Marsh Vulnerability Index can be developed for marshes dominated by certain indicator species. The individual marsh polygon elevations will be compared with the Marsh Vulnerability Index to estimate the sustainability of that particular marsh.

Phase IV will produce a Statewide Marsh Vulnerability Index for several indicator marshes throughout the State. Contiguous areas of indicator marshes along the Delaware Coast will be identified and these areas will be defined as polygons in Arc/GIS. A random sampling of the sites will be done to insure the proper identification of the species. Mean, median, maximum and minimum elevations will be determined for each marsh polygon, and actual marsh elevation will be determined with LiDAR data. Additional field sampling may be conducted to verify elevations. The tidal ranges and mean tide elevation will be determined for a range of regions along the Delaware Bay coast. Based on the maximum/minimum elevations derived from the Arc/GIS analysis, a refined indicator species tidal growth range (both species specific and composite indexes) will be developed. The indicator species in marshes throughout the State will then be classified based on marsh species structure, larger contiguous marshes will then be classified using the Marsh Vulnerability Index. The outcome of Phase IV is contingent upon Phase I and a positive index created for *Spartina alterniflora*.

#### ACTIVITIES/SCHEDULE:

1. *Phase I:* Develop *Spartina alterniflora* index for DNERR and CIB locations.
2. *Phase II:* Develop *Spartina alterniflora* index for coastal Delaware locations.
3. *Phase III:* Develop multiple species indexes for DNERR and CIB locations.
4. *Phase IV:* Develop multiple species indexes for coastal Delaware locations

<b>Activity</b>	<b># months req' for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	12	December 2010	Fieldwork Complete/ Processing In Progress
<b>2</b>	12	December 2011	In Progress
<b>3</b>	12	March 2012	Pending
<b>4</b>	12	March 2013	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS (Coastal Delaware Refuge Complex)

University of Delaware

## PRIME HOOK NWR SALINITY/NUTRIENT/SEDIMENT/WATER LEVEL STUDY

Coastal areas and natural resources are particularly vulnerable to climate change, especially with respect to accelerated sea level rise, shoreline erosion, increased storm frequency and intensity, changes in rainfall, and related flooding among other potential impacts. Investigation of such impacts, specifically salinity changes, nutrient inputs and sediment transport within the coastal impoundments at Prime Hook, will be conducted to determine the consequences of management practices and natural events.

Data collection will involve installing monitoring equipment to measure salinity and water level, and conducting salinity transects within the impoundments. Water quality will also be monitored, specifically total sediment solids (TSS) and nitrogen/phosphorus compounds to aid in determining sediment and nutrient fluxes in and out of the impoundments.

### GEOGRAPHIC LOCATION:

Prime Hook National Wildlife Refuge.

### OUTCOME:

This study will result in installation of real-time monitoring network; written reports that include summary of results; discussion of data analysis and statistical procedures. Results will be used to quantify current conditions in the impoundments and predict future changes of future management techniques.

### ACTIVITIES/SCHEDULE:

4. *Installation of monitoring equipment:* Install 7 water level and salinity recorders and set up real-time network
5. *Perform salinity transects:* Perform a series of salinity transects within impoundments II & III
6. *Collection of nutrient and sediment data:* Purchase of sampling equipment, design sampling protocols and collect data for seasonal baseline and storm conditions.
7. *Analyze data and write reports:* Data collected will be analyzed and interpreted leading to an interim reports. These report will be used as a basis for a more detailed study and support management efforts of the Refuge

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	2	Oct 2010	Completed
<b>2</b>	24	Oct 2012	Ongoing
<b>3</b>	24	Dec 2012	Pending
<b>4</b>	NA	Ongoing	Ongoing

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS

## SEDIMENT ELEVATION TABLES

Sediment elevation tables (SETs) provide a nondestructive method for making highly accurate and precise measurements of sediment elevation in intertidal and subtidal wetlands over long periods of time, relative to a fixed subsurface datum. Data collected using SETs can be used to determine both the influence of a single meteorological event on sediment surface elevation and a long-term trend in elevation change. This information will help increase our understanding of sedimentation rates in different marshes, sea level rise effects in these marshes, and potential management techniques.

This project will continue to collect data from established SETs within the St. Jones and Blackbird Creek estuaries. These SETs have datasets that began in 2004-2005 for Blackbird Creek and 2004 and 2007 for St. Jones River. The datasets contain total surface elevation change, shallow surface elevation change, sedimentation, deep subsidence, and shallow subsidence trends.

Marsh surface elevation changes are not merely being controlled by sediment deposition or erosion; subsurface processes are playing a major role in controlling elevation. Separating the influences of the biological (root growth), geological (soil compaction) and hydrological processes (groundwater storage) can be very difficult at best. Measurements from the deep benchmark will document and illustrate the effect that subsidence and compaction (the consolidation and dewatering of the fine grained material deep in the marsh sediments) are having on marsh surface elevation, with these changes in the zone of deep subsidence. The shallow benchmark will localize the effects that occur in the root zone (from the surface to ~ 30 to 50 cm below the sediment surface), such as enhanced growth due to nutrient fluxes, decomposition, compaction, dewatering, and pore water fluxes. Thus, it can be determined whether the subsurface influences are occurring (in the root zone or at deeper depths) and make a first approximation of which processes are dominating elevation change.

### GEOGRAPHIC LOCATION:

The project will be conducted within the St. Jones Estuary in Kent County, Delaware and the Blackbird Creek Estuary in New Castle County, Delaware.

### OUTCOME:

This study will result in a written report that includes a summary of results, discussion of data analysis and statistical procedures. Results can then be used to determine both the influence of a single meteorological event on sediment surface elevation and a long-term trend (i.e. decades) in elevation change, as well as make predictions for future elevation changes in our local marshes.

### ACTIVITIES/SCHEDULE:

1. *SET Monitoring:* SETs will be monitored and read in the St. Jones and Blackbird watershed every 3 months, approximately at the end of each season (i.e. fall, winter, etc.) on the same lunar cycle. Readings will take a total of 6 days per monitoring cycle (3 days each for the St. Jones and Blackbird), for a total of 24 field days for the year. Winter readings could be skipped due to high ice volumes on the marsh surface, which negate the ability to reliably measure the marsh surface.
2. *Status and Trends Report:* A status and trends report of the SET data will be drafted and peer reviewed every two years, for both the St. Jones and Blackbird SET networks. The first report will be completed by February 2011. The report will also include a gap analysis on the current coverage of SET networks across the state and highlight the gaps in spatial

distribution, and make recommendations for future SET placements that could help increase the wetland monitoring.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	On going	Expected 15 to 20 year data set (2019)	On going
<b>2</b>	2	First report, February 2011	On going

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

DNREC Watershed Assessment

Center for the Inland Bays

## IMPLEMENTATION ACTIONS

### CITY OF NEW CASTLE COASTAL RESILIENCY PROJECT

This project is designed to assist the community of the City of New Castle, Delaware in their efforts to reduce hazard vulnerability that currently exists and that could potentially increase in the future due to the impacts of climate change. The City of New Castle currently experiences a number of coastal related problems including; nuisance flooding of streets and road closures due to flooding; storm damage and erosion of dikes; periodic property flooding; and other coastal hazard impacts.

Before communities can develop effective hazard mitigation strategies, they must first identify their hazard risks and assess their vulnerability to the impacts of those hazards. This project will conduct a community-wide vulnerability assessment with broad community involvement and engagement. This will result in an action plan of prioritized projects designed to make the community more resilient, or at a minimum be prepared to recover, from damages associated with coastal hazards.

#### GEOGRAPHIC LOCATION:

City of New Castle

#### OUTCOME:

The goal of this project is to develop a community-wide action plan that increases the resiliency of the City of New Castle, Delaware to the current and future affects of coastal storms and climate change. The project will develop a proactive plan that outlines the specific vulnerabilities of the community and the best actions to be pursued to address these issues. This will include actions to address current risks as well as future risks associated with climate change, including the potential impacts of sea level rise, increased storm frequencies and intensities, tidegate and dike problems or failures, wetland loss, and other impacts.

#### ACTIVITIES/SCHEDULE:

1. *Data Collection and Synthesis:* DCP has submitted a Request for Qualifications (RFQ) in search of firms that will assist in collecting data on the existing tide gates and dikes. More specifically, the selected firm will:
  - a. Perform dike breach analysis and prepare inundation mapping for selected dikes around the City of New Castle
  - b. Perform tide gate analysis including functionality with anticipated sea level rise.
  - c. Prepare Emergency Action Plans for selected dikes around the City of New Castle.
  - d. Prepare Operation and Maintenance Manuals for dikes and tide gates around the City of New Castle.
  - e. Provide engineering support services to the Department as requested in response to dike-related incidents and emergencies including post-incident tasks such as data collection, review and assessment of structures and facilities, and assisting the Department or City of New Castle with planning, designing, and implementing dike repairs.

In addition, existing information will be analyzed and disseminated to provide a factual context to community members about their current storm flooding risk and vulnerabilities.

2. *Vulnerability Assessment:* Conduct a more detailed vulnerability assessment to be used as a guide for developing mitigation strategies and prioritizing mitigation projects.
3. *Strategy Development:* Utilize the detailed results of the vulnerability assessment to develop a final prioritization of needs and a set of strategies to address these needs.
4. *Action Plan Implementation:* A longer term effort to implement the action plan with short term assistance from DCP.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Data Collection and Synthesis</b>		October 2010	Dike Evaluation and Maintenance Plan preparation in progress
<b>Vulnerability Assessment</b>	-----	Summer 2011	In progress
<b>Strategy Development</b>	-----	Summer 2011	Developing workgroup for implementation planning
<b>Action Plan Implementation</b>	-----	Summer 2011	Not Started

#### AGENCIES INVOLVED:

DNREC Division of Watershed Stewardship

DNREC Division of Fish and Wildlife

Delaware Emergency Management Agency

New Castle County Emergency Management

Federal Emergency Management Agency

Delaware Department of Transportation

UD Sea Grant

City of New Castle

## DEVELOPMENT OF A COASTAL FLOOD MONITORING SYSTEM FOR DELAWARE

In the last two decades, storms such as Hurricanes Katrina and Ike along the Gulf of Mexico and Floyd and Hugo along the Atlantic Coast of the United States have resulted in significant loss of life, injuries and property damages reaching well over 100 billion dollars. Much of the damage associated with these and other tropical and extra-tropical weather systems is associated with severe coastal flooding. The Delaware coastline is extremely vulnerable to such events, examples being the great March 1962 storm and the recent coastal flooding incident of May 12, 2008 which left at least one person dead and many homeless after ocean flood waters destroyed homes, especially along the Delaware Bay Coast of Kent County. The added concern of sea-level rise and its effect on the frequency and intensity of coastal flooding events, further emphasizes the need for a modern, dependable coastal flood monitoring system for Delaware's coastal communities.

This project will develop a real-time coastal flood monitoring and warning system for the coastal communities within Kent County, Delaware. This system will serve as a prototype for similar protection along the entire Delaware coast. We will build on the existing competencies of the Delaware Environmental Observing System (DEOS) and the Delaware Geological Survey (DGS) in the development of this prototype system. The deliverables from this project will directly impact several State agencies including the Delaware Department of Natural Resources and Environmental Control (DNREC), the Delaware Emergency Management Agency (DEMA), the Delaware Department of Transportation (DelDOT) and the Delaware National Estuarine Research Reserve (DNERR). Moreover, the proposed system will have a direct impact upon the safety and well-being of Delaware's coastal communities. The system will allow State constituencies to be informed as to tidal conditions and possible flooding situations up to 120-hours in advance of their occurrence. Moreover, the system will indicate those areas that are most likely to be affected by any tidal flooding (roadways, facilities, homes, etc.) allowing for immediate response by appropriate State and County agencies.

### GEOGRAPHIC LOCATION:

Coastal Kent County Delaware

### OUTCOME:

When complete, DEOS and DGS observation sites will continuously monitor environmental conditions across the Delmarva Peninsula. The DEOS will also ingest forecasted tidal levels, based upon astronomical and meteorological conditions, provided through NOAA. When a forecasted (or real-time) critical tidal level is reached, the DEOS ALERTS system will send a message to all interested State officials warning that a coastal flooding situation is possible, which will prompt them to go to the Coastal Flood Monitoring web page. The web page will contain pertinent real-time and forecasted tidal and meteorological information as well as flood inundation maps for each major coastal community along the Kent County coast. Maps will be produced at appropriate flood levels using the latest LIDAR elevation data. Both paper (for dissemination to State and County agencies) and digital (for inclusion on the Coastal Flood Monitoring web page) maps will be produced.

Development of the system will proceed in tandem with the completion of the coastal monitoring GAP Analysis and the inland flood inundation survey. The GAP Analysis will both inform and be informed by the coastal flood monitoring system development. The survey of high water marks during previous coastal flooding events will be conducted using standard surveying techniques by the Delaware Geological Survey. High water marks will be identified, their history confirmed and

the inundation level recorded. This data will be used in conjunction with observed tide heights at USGS tidal monitoring points to better understand the inland inundation associated with various tidal levels along the coast. The association between tide levels at current coastal monitoring sites and inland flood levels is critical in developing statistical relationships that can be used in the development of a coastal flood model that accurately depicts possible inland flooding given a prediction of tidal anomalies at current monitoring sites.

#### ACTIVITIES/SCHEDULE:

1. *Data Collection & Database Modification:* Perform coastal flood inundation surveys, integration of “forecast” data into DEOS data base structure, initial production of flood inundation maps for coastal communities, modification of DEOS ALERTS system for forecast data.
2. *System Integration, Testing & Implementation:* Completion of flood inundation maps, testing of DEOS ALERTS system with forecasted data, development of Coastal Flood Monitoring web page, development of prototype coastal flood statistical model, implementation of system and final report of the project to be presented to DNREC.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	6	January 2010	Completed
2	9	October 2010	Completed

The website for the Coastal Flood Warning System can be found linked to the DEOS website at: <http://www.deos.udel.edu/index.html>

#### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware, Dept of Geography

Delaware Geological Survey

University of Delaware EPSCOR

## DEVELOPMENT OF A COASTAL RESILIENCY ACTION PLAN FOR BOWERS BEACH

Bowers Beach, Delaware is a small Bayfront community in Kent County located between the St. Jones and the Murderkill River. This small town is home to a small commercial fishing fleet and is a popular place for recreational boaters. Although its location makes it attractive for waterfront living and recreating, its location also makes the Town particularly vulnerable to the effects of coastal storms and sea level rise.

This project is designed to assist the community of Bowers Beach, Delaware in their efforts to reduce coastal hazard vulnerability that currently exists and that could potentially increase in the future due to the impacts of sea level rise. Bowers Beach currently experiences a number of coastal related problems including nuisance flooding of streets, episodic storm damage, coastal erosion, and other coastal hazard impacts.

The goal of this project is to develop a community-wide action plan that increases the resiliency of Bowers Beach, Delaware to the current and future effects of coastal storms and seal level rise. The project will develop a proactive plan that outlines the specific vulnerabilities of the community and the best actions to be pursued to address these issues. This will include actions to address current risks as well as future risks associated with climate change, including the potential impacts of sea level rise, increased storm frequencies and intensities, increased rates of erosion, salt water intrusion, wetland loss, and other impacts.

### GEOGRAPHIC LOCATION:

Town of Bowers Beach, Kent County, Delaware.

### OUTCOME:

The final outcome will be an action plan of prioritized projects designed to make the community more resilient, or at a minimum be prepared to recover, from damages associated with coastal hazards. The Town will also acquire the skills necessary to identify and seek out funding opportunities to finance project implementation.

### ACTIVITIES/SCHEDULE:

1. *Phase I-Data Collection and Synthesis:* This first phase of the project will include the collection, analysis, and dissemination of existing information to provide information to community members about their current storm flooding risk and vulnerabilities.
2. *Phase II-Vulnerability Assessment:* Phase two will include a detailed workshop(s) to gather further information and to conduct a detailed vulnerability assessment to be used as a guide for developing mitigation strategies and prioritizing mitigation projects. A Hazards Characterization workshop was conducted to collect the personal experiences from coastal storm and flooding events from the town residents, as well as to identify their initial concerns relating to these storm events. The information gathered during this workshop will be used by a technical workgroup, comprised of State and County experts in project planning and hazard preparations and town representatives, for development of a formal vulnerability assessment and initial mitigation strategy.

3. *Phase III-Strategy Development:* Phase three will utilize the detailed results of the vulnerability assessment to develop a final prioritization of needs and a set of strategies to address these needs.
4. *Phase IV-Implementation:* This phase will be a longer term effort to implement the action plan. Delaware Coastal Programs will take on an advisory role in assisting the town with procuring funding, project design and tracking.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Phase I</b>	9	Winter 2010	Drainage Study ongoing; project webpage published
<b>Phase II</b>	9	Winter 2010	Hazard Workshop conducted and summary document completed;  Assessment workshop conducted; Assessment workshop evaluation ongoing.
<b>Phase III</b>	9	Winter 2010 Spring 2011	-----
<b>Phase IV</b>	12	Spring 2011	-----

AGENCIES INVOLVED:

Town of Bowers Beach

Division of Watershed Stewardship -Shoreline and Waterway Management Section and Drainage Section

Delaware Emergency Management Agency

Kent County Emergency Management

Federal Emergency Management Agency

Delaware Department of Transportation

UD Sea Grant

## POLICY DEVELOPMENT

### DEVELOPMENT OF A STATEWIDE SEA LEVEL RISE ADAPTATION PLAN

Sea level rise will have economic, social and environmental effects throughout the State of Delaware. Sea level rise increases the height of storm waves, making more areas vulnerable to storm damage and can inundate low lying areas, causing losses to tidal wetlands, habitat, and agricultural areas. Sea level rise also can cause higher water tables and salt water intrusion, interfering with the septic systems, drinking water and irrigation water. These effects have implications for coastal access and recreation, transportation networks, public safety and land use patterns.

To address these issues, the Delaware Coastal Programs will develop a Statewide Adaptation Plan for Sea Level Rise. Using the data and information collected from other parts of the Sea Level Rise Initiative in combination with the expertise of many other agencies, the adaptation plan will recommend policy changes and practices that will ensure that Delaware makes informed policy and investment decisions today to prevent damage and losses to infrastructure, resources and homes tomorrow. Recommendations will be based upon a careful assessment of potential effects to landowners, communities, economies, natural resources and infrastructure using the best available science and technology.

Development of the Sea Level Rise Adaptation Plan will be guided by an Advisory Committee that is comprised of representatives from state agencies, municipal governments, business and development advocacy groups and environmental advocacy groups. Significant opportunities for public involvement will also be integral to the development of the plan.

#### GEOGRAPHIC LOCATION:

This project will be statewide.

#### OUTCOMES:

The final outcome of this project will be the publication of a Statewide Sea Level Rise Adaptation Strategy that will outline recommended policies and management strategies to reduce the State's vulnerability to the impacts of Sea Level Rise.

Additional outcomes will include:

- Proceedings Document: Sea Level Rise Issues Characterization Workshop
- Statewide Assessment of Delaware's Vulnerability to Sea Level Rise
- Proceedings Document: Sea Level Rise Adaptation Strategies Workshop
- Increased awareness of the impacts of Sea Level Rise at the state and local level
- Increased interagency coordination on Sea Level Rise issues
- Public outreach
- Implementation of strategies

#### ACTIVITIES/SCHEDULE:

1. *Initial Issues Characterization Workshop:* One-day workshop to begin discussing and outlining potential impacts of sea level rise in Delaware. This workshop was held in March, 2009.
2. *Formation of Advisory Committee:* Agencies and organizations will be invited to participate in the Sea Level Rise Advisory Committee and monthly meetings will convene.
3. *Vulnerability Assessment:* Advisory Committee and Delaware Coastal Programs staff will conduct a statewide screening assessment of Delaware's potential vulnerability to sea level rise.
4. *Strategy Development:* Recommendations for strategies to reduce Delaware's future vulnerability to sea level rise will be drafted by the Advisory Committee and during a public workshop. These strategies will be refined and made available to the public for comment prior to finalizing the document.
5. *Implementation of Priority Strategies:* Strategies will be ranked by the Advisory Committee. Funding and other resources will be sought to implement priority strategies.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	2	March 2009	Completed
2	2	November 2010	Underway
3	6	February 2011	Underway
4	8	October 2011	Not yet begun
5	**	**	Not yet begun

\*\* Implementation will be an on-going task with no certain end date

#### AGENCIES INVOLVED:

The following agencies and organizations were invited to participate in the Advisory Committee:

Delaware Department of Agriculture

Delaware Department of Health and Social Services

Delaware Department of Natural Resources and Environmental Control

Delaware Department of Transportation

Delaware Department of Safety and Homeland Security

Delaware Economic Development Office

Delaware Farm Bureau  
Delaware Insurance Office  
Delaware League of Women Voters  
Delaware Nature Society  
Delaware Office of Management and Budget  
Delaware Office of the Governor  
Delaware Realtors Association  
Delaware State Chamber of Commerce  
Home Builders Association of Delaware  
The Nature Conservancy, Delaware Chapter  
Positive Growth Alliance  
Tidewater Utilities, Inc.  
University of Delaware College of Earth Ocean and the Environment

## MID-ATLANTIC REGIONAL COUNCIL ON THE OCEANS (MARCO)

In June 2009 the Governors of Delaware, Maryland, New Jersey, New York, and Virginia convened a summit to mark the signing of the *Mid-Atlantic Governors' Agreement on Ocean Conservation* and the establishment of the Mid-Atlantic Regional Council on the Ocean (MARCO). Discussions held at the Governors Summit built on expert knowledge and led to the identification of initial actions that advance each of the Governors' four shared priorities. Under the MARCO umbrella the five states are working together to address the four priority issue areas which include: protection of sensitive and unique offshore habitat areas; support for the sustainable development of offshore renewable energy; prepare the region's coastal communities for the impacts of climate change on ocean and coastal resources; and promote improvements in the region's coastal water quality. MARCO has recently added a fifth priority to address coastal and marine spatial planning (CMSP) in light of the President's Ocean Policy Task Force recommendations to develop a national framework for CMSP. CMSP is seen by MARCO as a means to advance most, if not all, of the four priorities and each state is taking steps to aid in the development, coordination, and integration of coastal and marine spatial plans for the region.

The Governors Agreement also called for MARCO to hold a Stakeholder Workshop on the initial action plan. In December 2009, key state and federal agency representatives along with high-profile leaders of the full range of ocean interests learned from each other, deliberated, and made commitments to advancing MARCO's shared actions on its priority areas. Based on the valuable feedback and dialogue from the stakeholder workshop, MARCO is collaborating with federal partners to implement the priority actions and is drafting an updated action plan. The DCP hosted two two-day MARCO working meetings in May and August 2010 to further the state-federal partnerships and the updated action plan.

More information can be found on the MARCO website: [www.midatlanticocean.org](http://www.midatlanticocean.org).

### GEOGRAPHIC LOCATION:

Mid-Atlantic region, including the states of Delaware, New York, New Jersey, Maryland, and Virginia.

### OUTCOME:

MARCO will result in improved management of Mid-Atlantic coastal and ocean resources. The collaborative effort will improve outcomes by instituting a regional, ecosystem-based approach and will foster a cooperative and constructive relationship among the states. It will also provide leverage for greater federal investment and action on the states' coastal and ocean management priorities.

### ACTIVITIES/SCHEDULE:

1. *Refine action plan and implement recommendations:* The action plan will be refined based upon the results of the December 2009 stakeholder workshop, the Presidents' Ocean Policy Task Force recommendations and National Ocean Policy, and the recent two day workshop with federal representatives held in August 2010. The plan outlines the goals, specific objectives, and initial actions for each of the four priority areas. Each initial action specifies which state will take the lead on it, which objective(s) it advances, and a proposed timeframe or completion date.

2. *Working Meetings:* The DCP will host and/or attend quarterly/triannual MARCO working meetings for both state and federal representatives.
3. *Stakeholder Engagement:* MARCO is in the process of applying for Federal grant funds to help organize and facilitate stakeholder engagement workshop(s).
4. *ELI Policy Review:* The DCP has contracted with the Environmental Law Institute (ELI) to conduct a detailed review and assessment of the laws, policies, and programs related to offshore renewable energy development activities in the Mid-Atlantic states coastal zones and adjacent federal waters. This will focus on Delaware, but also include information from the other five MARCO states. ELI began work in September 2010 and is on schedule to complete by April 2011.
5. *Regional SLR Adaptation:* The DCP is the lead on addressing MARCO's goal of preparing the region for sea level rise impacts on regional infrastructure, coastal habitat, and shoreline management. DCP will guide the development of vulnerability assessments and sea level rise scenarios for the MARCO region and to promote regional information exchange about adaptation across the states.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	12	June 2011	In progress
2	12	October 2011	In progress
3	24	October 2012	Not yet initiated
4	6	March 2011	In progress
5	2	October 2012	In progress

**AGENCIES INVOLVED:**

States of Delaware, New York, New Jersey, Maryland, and Virginia

## SUSTAINABLE COASTAL COMMUNITIES

Most land use decisions in Delaware are made at the local level, yet those making decisions often lack technical expertise and/or planning resources. To address the lack of technical and planning resources, the Delaware Coastal Programs offers grants and technical assistance to local governments, state agencies and not-for-profit organizations for planning, natural resource management and coastal hazard mitigation.

In previous years, this funding and technical assistance has helped communities develop ordinances, incorporate natural resource considerations into comprehensive land use plans, inventory natural resources and restore important coastal habitats. In 2009 and beyond, the grant program will be more focused towards assisting community planning for reducing impacts resulting from coastal hazards and assessing vulnerabilities and risks to plan for future impacts of sea level rise.

### GEOGRAPHIC LOCATION:

Grants will be available Statewide, through a competitive RFP process.

### OUTCOME:

This program will result in improved management of Delaware's coastal resources through incorporation of coastal hazard and natural resource considerations into local comprehensive plans. This includes coastal storm resiliency planning, development of coastal management ordinances to reduce impacts, and educational outreach for Delaware's local governments.

The DCP anticipates funding and assisting with 3 – 5 projects per year.

### ACTIVITIES/SCHEDULE:

1. *Release RFP and Award Grants:* The funding will be announced through a “Request for Proposals.” Grant proposals received will be ranked by a committee of resource experts and successful grant applicants will be notified.
2. *Grants Management:* DCP staff will negotiate contracts for each grant recipient and will provide technical assistance until the project has been completed.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	4	December 2010	Underway
2	14	March 2012	Not yet underway

### AGENCIES INVOLVED:

Delaware Coastal Programs

## COMMUNICATION, TRAINING AND PUBLIC INVOLVEMENT

### COMPREHENSIVE MARKETING & OUTREACH STRATEGY FOR SEA LEVEL RISE

In order to effectively communicate to the public and decision maker audiences regarding sea level rise issues, the Delaware Coastal Programs (DCP) established a Sea Level Rise Outreach Strategy Committee comprised of educators, marketers, and communication specialists from the Delaware National Estuarine Research Reserve, Delaware Sea Grant, the Partnership for the Delaware Estuary, DNREC – Public Affairs, DNREC – Shoreline and Waterway Section, in addition to staff from DCP to develop a comprehensive sea level rise marketing and outreach strategy. The strategy provides a clear, coordinated message with information and materials developed and disseminated by all of the organizations of the Committee including Delaware Coastal Programs, Delaware National Estuarine Research Reserve.

As part of the development of this comprehensive strategy, a statewide survey to gauge public knowledge and opinions on sea level rise and its impacts on Delaware was completed in the spring of 2010. This survey provides information about Delaware residents' awareness and understanding of key issues regarding climate change and sea level rise; determine their perception of its overall effect on the economy and ecology of the state; and explore public opinion regarding long range planning for sea level rise loss and damage prevention. Using the results of this survey, as well as other studies and reports focused on improving communications on sea level rise and climate change, a comprehensive marketing and outreach strategy has been drafted to enhance the public and coastal stakeholders' awareness and response to sea level rise.

The strategy considers a variety of audiences (such as local, county, and state government officials, local and regional planners, economic development representatives, agriculture representatives, university researchers, educators, and property owners) and includes workshops, seminars, brochures, factsheets, public service announcements, media buys, website development and/or outreach displays.

#### GEOGRAPHIC LOCATION:

Statewide

#### OUTCOME:

A comprehensive marketing and outreach strategy and an implementation/work plan have been drafted.

#### ACTIVITIES/SCHEDULE:

1. *Strategy Development:* An inventory of existing Sea Level Rise marketing and outreach programs will be completed and will be analyzed along with results of the Sea Level Rise Attitudes and Perception Survey. This analysis will then be interpreted to design a targeted Marketing and Outreach program.
2. *Strategy Implementation:* Activities listed in the strategy will be implemented.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	4	Fall 2010	Draft Completed
<b>2</b>	Ongoing as needed	-	Underway

#### AGENCIES INVOLVED:

##### DNREC

Delaware Coastal Programs

Division of Watershed Stewardship/Shoreline & Waterway Management

Public Affairs

Delaware Sea Grant

Partnership for the Delaware Estuary

Responsive Management

## SEA LEVEL RISE INTERNET MAP VIEWER

Land-use decisions in Delaware are primarily made at the local level yet, often these smaller towns lack the GIS infrastructure that would allow large scale planning efforts, particularly those related to coastal hazards. Delaware Coastal Programs has made significant investment in GIS data, personnel, and hardware over the years. Transferring the benefits of this investment to community decision makers is vital to the success of these planning efforts.

As part of DCP's efforts assisting local governments with Coastal Hazard and Community Resilience Planning, data will be created and shared with the local decision makers and the community. Internet based mapping applications can be a useful tool to affect this sharing. Most local governments and citizens have access to basic internet browsers either at home or in public libraries. Online mapping tools such as Google Maps and Virtual Earth provide free, lightweight mapping tools that members of the public can use to participate in planning efforts. More robust applications, such as ArcGIS Server and Google Earth, allow for more complex views of Community Resiliency information while keeping costs at a minimum (i.e. free to end user). The choice of tool used will depend on the needs of the user and the ability of the tool to present the data.

DCP has utilized ArcGIS Server to produce and distribute Statewide Sea Level Rise Inundation maps for these planning efforts. KML versions of the data are available, however, the datasets are too large to be conveniently accessed on slower internet connections. ArcGIS Server provides both a freely accessible viewer for the general public and advanced access for GIS users to a map service.

### GEOGRAPHIC LOCATION:

Maps of DNEC's Sea Level Rise Inundation Scenarios are available statewide. Distribution of more localized data will initially focus on individual communities undergoing resiliency planning (i.e. Town of Bowers and City of New Castle).

### OUTCOME:

Website(s) providing citizen access to Community Resilience Planning Maps.

<http://www.dnrec.delaware.gov/Pages/SLRMaps.aspx>

### ACTIVITIES/SCHEDULE:

1. *Software needs assessment and acquisition:* Evaluate capabilities of various software to provide mapping data to public through open GIS browsers. Acquire selected software.
2. *Data List:* Develop and initial list of data to be distributed to community members.
3. *Data Conversion:* Convert selected data and maps for distribution.
4. *Website creation:* Establish a new set of pages within DCP's Sea Level Rise web section for distribution of mapping information.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	1 month		Complete
<b>2</b>	1 month		Complete
<b>3</b>	1 month		Complete
<b>4</b>	1 month		Complete

AGENCIES INVOLVED:

Delaware Coastal Programs

DNREC – Office of Information Technology

## STATEWIDE SURVEY TO GAUGE PUBLIC KNOWLEDGE AND OPINIONS ON SEA LEVEL RISE AND ITS IMPACT IN DELAWARE

In order to effectively plan and target sea level rise outreach and technical assistance, it is important to understand the public perception of sea level rise. However, there is currently no statewide information available regarding the level of knowledge Delawareans possess regarding sea level rise and its future impacts; nor whether Delawareans are motivated to change their behaviors to reduce their risk to impacts associated with sea level rise.

In order to address this need, the Delaware Coastal Programs, in cooperation with The Nature Conservancy and with contractual assistance from Responsive Management Inc. conducted a statewide telephone survey during the fall 2009. The survey was designed to be statistically significant and to assess Delaware residents' awareness and understanding of key issues regarding climate change and sea level rise; to determine their perception of its overall effect on the economy and ecology of the state; and to explore public opinion regarding long range planning for sea level rise loss and damage prevention.

The survey was completed in January 2010 and is available for download online:  
<http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/SLRSurveyReport.pdf>

### GEOGRAPHIC LOCATION:

The telephone survey was conducted statewide.

### OUTCOME:

The survey resulted in a written report that includes a summary of results; discussion of data analysis and statistical procedures, a tabular data report, survey graphs and tables, frequency distributions and cross-tabulations. The report has since been used to help in the development of an outreach and marketing strategy, and to guide the content of other outreach and educational products.

### ACTIVITIES/SCHEDULE:

1. *Develop survey instrument:* In cooperation with other interested agencies and Responsive Management, design and test the survey.
2. *Conduct Telephone Survey:* Responsive Management will conduct the phone survey using random dialing.
3. *Analyze Results:* Responsive Management will analyze the results of the survey with appropriate statistical tests.
4. *Prepare Report:* Responsive Management will prepare a final report that provides an executive summary, methodology, data and appropriate charts and graphs.
5. *Distribute and Explain Report:* Final report will be made available via the web and hard copy. Workshops will be held in cooperation with the Nature Conservancy and Responsive Management to explain the results of the survey.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	2	July 2009	Complete
<b>2</b>	2	November 2009	Complete
<b>3</b>	2	December 2009	Complete
<b>4</b>	1	January 2010	Complete
<b>5</b>	6	March 2010	Complete

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

The Nature Conservancy

Responsive Management

PREPARING FOR SEA LEVEL RISE  
DEVELOPMENT OF A SEA LEVEL RISE INITIATIVE

Sea Level Rise Initiative  
Project Compendium  
October 2010



*Photo by: Delaware Shoreline and Waterway Management Section*

*A Compendium of Delaware Coastal Programs' Projects that Address  
Sea Level Rise*



Delaware Coastal Programs

(302) 739-9283



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## THE SEA LEVEL RISE INITIATIVE

In recognition of the importance of the coast to the Nation's commerce, energy development and natural resource protection, the Coastal Zone Act of 1972 was enacted to assist States manage these conflicting uses of coastal areas. At that time, in addition to directing State Coastal Zone Management Programs to address issues of pollution, development, navigation and energy development, the Coastal Zone Act also directed States to prepare for sea level rise.

In recent years, improved climatic and ocean observation systems have made it possible for scientists to better assess the potential for sea level rise and make predictions for the future. These predictions have shown that coastal areas, particularly in the Mid-Atlantic states, will likely see an increased rate of sea level rise. The U.S. Climate Change Science Program's (CCSP) 2009 document, "Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic" recommends that states should prepare for sea level to rise by at least one meter (39 inches) by 2100; the current rate of sea level rise measured by a tide gauge in Lewes Delaware is 13 inches per 100 years. The CCSP prediction is in close agreement with many other predictions by Federal, State and Global agencies and represents a three-fold increase in the historic rate of sea level rise.

This level of sea level rise will have economic, social and environmental effects throughout the State of Delaware. Sea level rise will inundate low lying areas, causing significant losses to tidal wetlands and wildlife habitat. As the high tide line encroaches landward, some important agricultural areas may no longer be suitable for tillage. Sea level rise also can cause higher water tables and salt water intrusion, interfering with the septic systems, drinking water and irrigation water. Most importantly for many coastal communities, sea level rise can increase the effects of storm surge and waves, allowing flooding to occur in areas that may have never previously been susceptible to flooding from storms. All of these potential effects from sea level rise also have implications for coastal access and recreation, transportation networks, public safety and land use patterns.

To help assess, prepare for and minimize the potential impacts of sea level rise, the Delaware Coastal Programs Section of the Delaware Department of Natural Resources and Environmental Control is leading a multi-year Sea Level Rise Initiative. The goal of the Sea Level Rise Initiative is to reduce Delaware's future vulnerability to the effects of sea level rise. This will be accomplished by:

- Providing scientific and technical support for decision-making
- Implementing on-the-ground project in partnership with stakeholders
- Providing educational and outreach opportunities for stakeholders and the public
- Improving existing policies and management practices and/or developing new policies and management practices where necessary

As part of the goal of providing scientific and technical support for decision-making, Delaware Coastal Programs scientists have partnered with the National Wildlife Refuge System, the University of Delaware, local Estuary Programs and other state agencies to fill gaps in our knowledge about coastal storms, tide levels and marsh sediment accretion. This data and information will be used for policy development; communication of this new information is a component of the outreach strategy.

As part of the goal of implementing on the ground projects, Delaware Coastal Programs staff have partnered with the City of New Castle and the Town of Bowers Beach to help them improve their

preparedness for coastal storms and future sea level rise. Related to this effort, and using high resolution elevation data, a real time flood monitoring system is being developed that will greatly improve flood response in coastal communities.

Public involvement and outreach is a critical component of preparing for sea level rise. All of the tools and data developed during the Sea Level Rise initiative will be communicated to the public through websites, presentations, public events, articles and decision-maker workshops. This is detailed in a comprehensive outreach strategy for sea level rise, developed in partnership with the DNREC Watershed Stewardship Division, the Delaware Estuary Program and Delaware Sea Grant.

These projects, along with others described in this document, have been initiated under the Sea Level Rise Initiative to help to build partnerships and capacity, increase resiliency, increase public knowledge of and support for actions to reduce our vulnerability and make decisions based upon the best available science. The Sea Level Rise Initiative is designed to be iterative and will grow and change as new data, outreach and policy needs are identified.

## PURPOSE OF COMPENDIUM OF SEA LEVEL RISE INITIATIVE PROJECTS

The purpose of the Sea Level Rise Initiative Compendium of Projects is to provide an at-a-glance inventory of the projects and initiatives are being conducted as part of the Delaware Coastal Programs' Sea Level Rise Initiative. It is intended to help increase collaboration between agencies, reduce redundancy and overlap in projects relating to sea level rise and to relay information about new (or soon to be available) data, information and tools.

Projects conducted without the assistance or involvement of the Delaware Coastal Programs are not currently reflected in this document. However, there are many other agencies whose work will be essential to preparing for sea level rise and coastal inundation. The Delaware Coastal Programs may in the future consider expanding the scope of this document to include other agencies' work.

Because the projects listed in this document are likely to evolve over time, it is our intent to update this document on a routine basis so that our partner agencies can be kept up to date on sea level rise activities. The most current version of the document will be posted on the Delaware Coastal Programs' sea level rise website.

## FOR MORE INFORMATION

For more information about projects contained within the Sea Level Rise Initiative Compendium, please contact us at (302) 739-9283 or see our website:

<http://www.swc.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx>

## SCIENTIFIC AND TECHNICAL SUPPORT

### BOMBAY HOOK HYDROLOGY/SEDIMENT MOVEMENT STUDY

Coastal areas and natural resources are particularly vulnerable to climate change, especially with respect to accelerated sea level rise, shoreline erosion, increased storm frequency and intensity, changes in rainfall, and related flooding among other potential impacts. Investigation of such impacts, specifically marsh depletion and increased mudflats at Bombay Hook, will be conducted to determine patterns of sediment flux in or out of the depleted marsh area.

Data collection will involve conducting river transects within the Leipsic River using the Acoustic Doppler Current Profiler (ADCP) and associated software to collect and process tide and current data. Water quality will also be monitored, specifically total sediment solids (TSS) to aid in determining sediment fluxes in or out of the depleted marsh area.

#### GEOGRAPHIC LOCATION:

Bombay Hook National Wildlife Refuge.

#### OUTCOME:

This study will result in a written report that includes a summary of results; discussion of data analysis and statistical procedures. Results will be used to predict future changes in marsh depletion and to help determine marsh management techniques to counteract these impacts affecting the tidal marshes at Bombay Hook.

#### ACTIVITIES/SCHEDULE:

1. *Installation of monitoring equipment:* Install 5 water level recorders and 1 Acoustic Doppler Current Profiler.
2. *Perform cross-section current profiles and collect data:* Perform a series of cross-section current profiles at various locations over varying tidal stages and collect water level and ADCP data.
3. *Analyze data and write report:* Data collected to date will be analyzed and interpreted leading to an interim report. This report can be used as a basis for a more detailed study and support future modeling efforts in the Refuge

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	1	May 2009	Completed
<b>2</b>	NA	Ongoing	Ongoing
<b>3</b>	3	March 2011	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS

## COASTAL IMPOUNDMENT ACCRETION RATE STUDY

As an accelerated rate of relative sea-level rise further stresses impounded marshes, there is a greater need to evaluate the long-term sustainability and utility of impoundments in Delaware. In order to do this, baseline data regarding historic sedimentation rates is needed.

Baseline data sets of long-term sedimentation rates in impounded and natural wetlands can be utilized to evaluate the impounded wetlands' ability to achieve optimal habitat benefit under different management strategies and under different sea level rise scenarios

Long-term sedimentation rates over the past 100 and 50 years can be calculated by collecting radioisotopic cores from wetland areas and analyzing them for  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$ . All core sites and the adjacent wetland will be surveyed to tie all data to the tidal datum (NAVD 88). Correlating long-term wetland sedimentation rates to current wetland elevation will enable a detailed analysis of the potential sedimentation deficits that exist within the impoundments, as compared to the reference wetlands. The elevation and sedimentation gradients between the reference and impounded wetlands can be used to calculate potential future elevation trajectories under different sea-level rise and management scenarios.

### GEOGRAPHIC LOCATION:

Monitoring sites were chosen within impounded and reference (natural marsh) sites throughout the State based upon a wetland area change analysis (using a time-series of available imagery), and basins that have been identified as needing detailed study to aid in their management to optimize the future available habitat. Sites that will be studied include: marshes along the Delaware River near New Castle; Ted Harvey Wildlife Area; St. Augustine Wildlife Area; and Primehook National Wildlife Refuge.

### OUTCOME:

When complete, this study will provide information to coastal managers regarding marsh susceptibility to sea level rise under different marsh management scenarios and under different sea level rise scenarios. A long-term comparison of the wetland elevation and sedimentation conditions between the impounded marsh and the "natural" marsh will enable a detailed analysis and comparison of the potential long-term growth conditions and highlight the potential implications for impoundment management that could affect the sustainability of the interior wetlands. This information will allow marsh managers to understand the potential outcomes of sea level rise and adapt their management techniques.

### ACTIVITIES/SCHEDULE:

1. *Initial Impoundment Core Collection:* Radioisotopic cores will be collected from selected marshes. All core sites and adjacent wetlands will be surveyed. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis is scheduled to be complete by December 2009.
2. *New Castle Impoundment Core Collection:* Radioisotopic cores will be collected from 3 impoundments and 2 reference marshes along the Delaware River adjacent to the City of New Castle. All core sites and adjacent wetlands will be surveyed after collection. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis is expected to be complete by December 2010.

3. *Kent County and Lower New Castle County Impoundment Core Collection:* Radioisotopic cores will be collected from Ted Harvey Wildlife Area, St. Augustine Wildlife Area, and Primehook National Wildlife Refuge. The Ted Harvey and St. Augustine sites were selected to expand the scope of the impoundment investigation to include sites along the entire Bay and River coast. All core sites and adjacent wetlands will be surveyed after collection. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis by UD is expected to be completed by December 2011.
4. *Gap Analysis of Delaware Coast:* A gap analysis of the Delaware River and Bay Coast Impoundments and reference marshes will be conducted to identify areas where additional cores should be collected and analyzed. The previously analyzed cores will be examined to evaluate the spatial and temporal variability within the study areas and evaluate the need for additional coring sites. A total of 18 cores will be collected to fill in the identified data gaps and areas of high spatial sedimentation rate variability.

<u>Activity</u>	<u># months req'd for completion</u>	<u>Activity Start Date</u>	<u>Estimated DCP Completion Date</u>	<u>Estimated Laboratory Completion</u>	<u>Status</u>
1	5	November 2008	March 2009	April 2010	In Progress
2	8 - 10	April 2009	November 2009	December 2010	In progress
3	6	December 2009	May 2010	December 2011	Pending
4	8	May 2010	January 2011	December 2012	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

UD College of Earth, Ocean and Environment

Primehook National Wildlife Refuge (USFWS)

DNREC Division of Fish and Wildlife

## COASTAL MONITORING GAP ANALYSIS

In the last two decades, storms such as Hurricanes Katrina and Ike along the Gulf of Mexico and Floyd and Hugo along the Atlantic Coast of the United States have resulted in significant loss of life, injuries and property damages reaching well over 100 billion dollars. Much of the damage associated with these and other tropical and extra-tropical weather systems is associated with severe coastal flooding. The Delaware coastline is extremely vulnerable to such events, examples being the great March, 1962 storm and the recent coastal flooding incident of May 12, 2008.

As part of a cooperative effort between the University of Delaware and several Delaware State Agencies to better monitor conditions along the Delaware coastline and to provide advance warning of impending coastal flooding events, we propose the completion of a GAP Analysis of pertinent coastal data needs and a comprehensive survey of inland inundation levels during previous coastal flooding events. The GAP Analysis will define the present state of coastal data collection efforts across the state, an “optimum” data collection network and the gap between them, indicating those data that need to be added to the current network. A survey of high water marks from previous coastal flooding events will be used to create a “baseline” data set to aid in understanding the relationships between water levels at tidal monitoring points and inland locations. In this research, an exhaustive inventory of real-time and archived coastal data will be conducted. This inventory will include meteorological, tidal, buoy, water quality and inundation data sources, along with ancillary sources of coastal information (i.e. research publications, modeling work, etc.).

### GEOGRAPHIC LOCATION:

Coastal Delaware.

### OUTCOME:

The final outcome/product will be a report that makes recommendations as to the type of data needed to reach an “optimum” coastal monitoring network, and the spatial placement and temporal resolution of additional sensors that may need to be deployed to reach the optimum configuration. The report is available at:

[http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Gap\\_Analysis\\_Final\\_Report\\_032910.pdf](http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Gap_Analysis_Final_Report_032910.pdf) or <http://www.deos.udel.edu/delawaregap/index.html>

### ACTIVITIES/SCHEDULE:

1. *GAP Analysis Report:* University of Delaware will conduct the analysis and develop a report that makes recommendations as to the type of data needed to reach an “optimum” coastal monitoring network.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	9	March 2010	Completed

### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware

## COASTAL STORM HISTORY

Several coastal communities in Delaware currently experience storm damage, coastal erosion, and other coastal hazard impacts. In efforts to reduce hazard vulnerability that currently exists and that could potentially increase in the future due to climate change impacts, the Delaware Coastal Programs, along with the University of Delaware are compiling data on historical storms, nor'easters, subtropical storms or hurricanes that may have impacted Delaware's coasts in the past.

This data was previously compiled by the University of Delaware for years up through 1974 and a written report is available. This project will focus on updating the storm data from 1974 to 2009.

### GEOGRAPHIC LOCATION:

Coast of Delaware.

### OUTCOME:

Compendium of historical storm data categorized according to the type of storm, physical characteristics and impacts on coastal communities and natural resources. This can perhaps be used to derive specific scenarios to be modeled for the purpose of future adaptation and preparedness. It will also help to identify where outside expertise should be brought in to provide additional technical assistance for resiliency assessment, planning and implementing. Depending on the detail of the data collected, there may be some insight for prediction of the next potential storm, nor'easter or hurricane and the impacts of such events.

### ACTIVITIES/SCHEDULE:

1. *Storm data collection:* Through analysis of historic data sets and communication with local and state officials and the public, historic storm information will be compiled.
2. *Development of Report:* A compilation report will be developed and distributed. The report will include storm data from 1974 to present including all pertinent data.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Contract signed</b>	n/a	Feb 2010	Completed
<b>1</b>	12	Sept 2010	Completed
<b>2</b>	6	March 2011	Pending

### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware

## DEVELOPMENT OF COASTAL INUNDATION MAPS

Sea Level Rise inundation maps are necessary to determine areas and extent of coastal vulnerability to sea level rise, and will be a key component guiding the development of a Statewide Sea Level Rise Adaptation Plan. While it is relatively straight forward to overlay elevated sea level changes onto existing digital elevation models (DEMs), certain factors must be considered. Primarily, mean tide levels vary along the Delaware Bay Coast and any maps developed must take this into consideration. Secondly, solely using sea level rise will not give a true perspective of inundation, since the major concern will be the flooding from coastal storm surges.

To develop these maps (GIS Layers) a statistical evaluation from the existing 2 long-term NOAA tide level datasets of Lewes (Breakwater Harbor) and Delaware City (Reedy Point) will be performed to establish storm surge elevations above Mean Higher High Water (MHHW) for selected return periods (i.e. 10, 25 50, 100-year return periods). Once these are calculated, the current MHHW levels along the length of the coast will be determined using the NOAA VDatum software. These two datasets will be combined to establish the appropriate elevations to use for coastal inundation. After the Delaware Bay coast is completed, a similar effort will be performed for the Inland Bays and Atlantic Coast.

### GEOGRAPHIC LOCATION:

Coastal Delaware

### OUTCOME:

The final outcome/product will be a series of maps in GIS format that will be based on the bare earth LIDAR data. Several scenarios will be developed using on current sea level rise, predicted average sea level rise and predicted maximum sea level rise for the years 2050 and 2100. Estimates of storm surge added to the predicted elevations will also be provided. These surges will be based on historic data and statistical analysis.

### ACTIVITIES/SCHEDULE:

1. *Statistical Analysis of existing tide data:* Based on existing data for Lewes and Delaware City, develop expected storm surge levels for certain return periods.
2. *Determine MHHW for Bay Coast:* Using VDatum, determine MHHW along Delaware Bay coastline corrected to NAVD88
3. *Develop Inundation Maps for Delaware Bay Coast:* Combining the two developed datasets, produce GIS maps for different seal level and storm surge scenarios
4. *Inland Bays and Atlantic Coast Maps:* Repeat 1-3 for Inland Bays and Atlantic Coast.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	2	September, 2009	Completed
2	<1	October, 2009	Completed
3	2	December, 2009	Completed
4	1	January, 2010	Completed

**It is anticipated that all inundation maps will be frequently updated as new information on sea level rise becomes available.**

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

## DIGITAL COAST

The Digital Coast is a nationwide initiative that is designed to ensure the wise use and management of coastal resources by providing coastal managers with data, training, tools and examples to assist them with emerging and priority coastal issues. The partner network identifies Digital Coast priorities and then works together to address coastal issues.

Currently, the Digital Coast partnership is focused on providing data, tools and examples to coastal managers regarding coastal inundation and sea level rise. Projects to address other coastal issues (i.e., marine spatial planning, conservation) will be developed in the future.

One of the goals behind the creation of the Digital Coast was to unify groups that might not otherwise work together and build a strong collaboration of coastal professionals intent on addressing coastal conservation needs. The Digital Coast Partnership Group is currently comprised of representatives from the Association of State Floodplain Managers, the Coastal States Organization, the National Association of Counties, the National States Geographic Information Council, The Nature Conservancy, and the NOAA Coastal Services Center. Delaware Coastal Programs staff has actively served as part of the Coastal States Organization representatives on this project. The National Oceanic and Atmospheric Administration's

(NOAA) Coastal Services Center is the lead organization for Digital Coast efforts.

### OUTCOME:

In the fall of 2009, the Coastal Inundation Toolkit, was released. The toolkit was being developed by the Digital Coast Partnership Group to help communities understand and address coastal inundation issues. Website components include:

- Understand – Learn about inundation basics and common hazard concepts
- Identify – Download the county-specific charts and graphs that tell your story
- Map – Use the steps provided to discover and map areas of potential impact
- Assess – Use inundation maps to assess community risk, vulnerability, and resilience
- Inform – Use risk communication strategies to illicit change
- Discover – See how other communities are addressing this issue

This tool is expected to be of enormous value as a resource tool for the many groups concerned with and working to address coastal flooding and Sea Level Rise issues in Delaware.

Current and future Modules of Digital Coast resources are available at:

<http://www.csc.noaa.gov/digitalcoast/>

## HYDROLOGIC MONITORING OF THE KITTS HUMMOCK AREA

To properly understand the relationships between the Delaware Bay, interior marsh water levels, ponds, impoundments and the drainage ditch network around Kitts Hummock, a comprehensive water level monitoring program will be established. Establishing a water level monitoring network at key locations will aid in the understating the interrelationships between the water bodies and the influence of the drainage network in the community on these water bodies. This baseline monitoring is one of the prerequisite needs for conducting any defensible modeling and evaluation of the effectiveness of any proposed drainage improvements to the Kitts Hummock area. Additional needs prior to modeling include validation of marsh elevations, detailed documentation and assessment of previous storms, and engineering designs of proposed alterations

This baseline network will use a total of 8 Inset HOBO water level recorders in conjunction with the USGS Tide gauge located approximately 5 kilometers south at Bowers Beach and other currently monitored parameters. Two water level recorders will be placed on the north and south sides of Kitts Hummock Road in the primary N/S drainage ditch approximately 250 meters inland from the Delaware Bay. An additional three water level recorders will be used to examine the effects of marsh water elevation and the northern impoundment of the Logan Lane Tract of the Ted Harvey Conservation Area on the open water area of a private property and the South Bay Drive drainage ditch. The final two water level recorders will be installed in open water areas of the marsh northeast of the community of Kitts Hummock to estimate the tidal backwater effects north of Kitts Hummock Road. A final recorder will be housed at the Delaware National Estuarine Research Reserve (DNERR) to measure barometric pressure changes which will be used to atmospherically correct the readings of the water level recorders. The recorders will be surveyed to an accuracy of  $\pm 2$  cm vertical, and maintained and downloaded monthly by staff from the DNERR.

### GEOGRAPHIC LOCATION:

This project encompasses the area surrounding Kitts Hummock, Kent County, DE, including the private marsh lands north and south of the community and the DNREC/DFW Logan Lane Tract of the Ted Harvey Conservation Area.

### OUTCOME:

Once sufficient data has been collected, which includes a minimum of 3 months of data and at least 3 significant storm events, the data will be compiled. Data on rainfall and wave height, period and direction, currently being monitored by the DNERR, will be incorporated into the data set and then the dataset will be analyzed. This analysis will include examining the Bay tide effects on marsh water/drainage ditch elevations; relationships of surrounding water levels on the Thompson open water area; probable pathways of tide related flooding; and a qualitative evaluation of the expected effectiveness of drainage ditches in the area during different tidal cycles/storm events.

### ACTIVITIES/SCHEDULE:

1. *Data Collection:* Install data recorders, survey locations and collect data.
2. *Data Analysis:* Analyze data, run computer simulations, develop qualitative evaluation of storm event drainage scenarios.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	3-5	October 2009	Complete
<b>2</b>	3	December 2009	Complete

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

DNREC Drainage and Stormwater Section

DNREC District Operations

## MARSH LOSS ANALYSIS (INTERIOR OPEN WATER CREATION)

Staff from Bombay Hook NWR contacted the Delaware Coastal Programs for assistance with their 5-year Biologic Review of the refuge. Refuge staff felt that DCP's experience with GIS analysis could help them answer some questions they had about the changing habitat of the refuge. Coastal change, rising sea levels, erosion and land subsidence are increasingly tough issues facing coastal managers, engineers, and planners charged with developing and protecting coastal habitats and communities in vulnerable coastal zones. Understanding these threats depends on early detection, and solutions will require vigorous public debate over engineering solutions vs. strategic retreat. The drastic changes at Bombay Hook National Wildlife Refuge (NWR) may be a harbinger of coast-wide habitat changes in the future.

The coastal areas of Bombay Hook NWR have historically been subjected to significant erosion. Historical shorelines from as far back as 1842 paint a much different picture than exists today. Shores that face the East and Southeast take the worst damage. These areas have the longest fetch allowing the winds to add more power to the waves that break on these shores. For the period 1937-2002, roughly 1700 ft. of erosion occurred along the southern shoreline of Bombay Hook (26 ft/yr). This habitat loss is now coupled with increasing amounts of open water creation in the interior marsh.

Aerial photos from 1979, 1992, and 2002 were examined for expansion of open water areas in the interior marsh. Photos were viewed on a geographic information system and areas of open water were outlined. Results showed that, over the years, open water areas were growing larger and combining together. What had been a mosaic of small areas of open water mixed in vegetated marsh are becoming large tracts of open water with vegetation around the edges. This Study revealed that since 1979, the Refuge has lost a total of 12% of its wetland area; 10% attributed to the creation of interior, open water areas.

No single, direct cause for the wetland loss has yet been identified. Some potential causes including sea level rise, marsh/land subsidence, and snow goose grazing are being looked into. These effects are inter-related and tend to work together to make matters worse. Currently DCP and others are using sediment elevation tables to explore subsidence and sedimentation in regional marshes. It is hoped that if a cause(s) can be determined, adjustments in marsh management can be made to stem the loss of interior area.

This project will investigate the expansion of open water areas in four additional areas throughout the state: the Thousand Acre Marsh region; Blackbird Creek; Milford Neck and Primehook National Wildlife Refuge. For each area, open water areas will be digitized using ArcGIS from historic aerial photographs to determine extent of open water areas over time.

### GEOGRAPHIC LOCATION:

DCP is now expanding the study to other similar marsh areas around the State: 1000 Acre Marsh, Blackbird Creek, Milford Neck Wildlife Area and surrounding private conservation lands; and Prime Hook NWR with nearby areas in Broadkill Beach.

#### OUTCOME:

This project will result in GIS maps of marsh loss over time for the study areas.

It is also hoped that this information can be combined with results from other studies and may shed light on the causes of the wetland loss. This combination of information is expected to lead to management changes that can limit further loss and possibly aid recovery of the marshes.

#### ACTIVITIES/SCHEDULE:

1. *Digitize open water areas:* Bombay Hook.
2. *Digitize open water areas:* 1000 Acre Marsh.
3. *Digitize open water areas:* Blackbird Creek.
4. *Digitize open water areas:* Milford Neck.
5. *Digitize open water areas:* Prime Hook.

Activity	# months req'd for completion	Estimated Completion Date	Status
1.			Complete
2.			Complete
3.			Complete
4.			Complete
5.			Complete

#### AGENCIES INVOLVED:

Delaware Coastal Programs

## MARSH VULNERABILITY INDEX

An index is needed to allow assessment of the long-term viability of Delaware's marshes under differing sea level rise scenarios and to target areas for conservation, restoration and monitoring. The Tidal Marsh Vulnerability Index will be based upon the positive correlation between mean tidal range and elevational growth range of tidal wetland plant species. Biomass sampling, taken from the Mid-Atlantic Wetland Rapid Assessment Method (MidTRAM), will also be incorporated into the Marsh Vulnerability Index to assess marsh health. Once developed, the Sea Level Rise Index for Tidal Marshes tool could be transferred to other states and used for regional comparisons and regional planning.

The Tidal Marsh Vulnerability Index will classify marshes as healthy, degrading or severely degrading. These classifications will be utilized to select areas to conduct detailed sediment accretion rate and other monitoring. Degraded and severely threatened marshes are known to have lower elevations, relative to the tidal prism, and are more prone to catastrophic losses due to sea-level rise and storm events. Understanding the current and historic sedimentation accretion rates of these marshes can help to better predict the longevity and the sediment deficits of these areas and possible management practices that might be implemented to prevent marsh elevation losses (i.e. thin layer application of sediment, vegetation plantings, etc.).

The Tidal Marsh Vulnerability Index, in conjugation with time-series analysis of aerial imagery, will be essential for evaluating wetland vulnerability on a watershed or statewide basis, while enabling the strategic placement of monitoring resources to enhance our efforts to understand the future evolution potential of Delaware's tidal wetlands. All field based monitoring and sampling efforts can be initiated and implemented to evaluate the most severely threatened marsh areas first; the monitoring can then be expanded to encompass other marsh regions as resources become available. Marsh Vulnerability Index classification optimizes the monitoring efforts and resources to the highest levels possible, so the broadest extent of Delaware's tidal wetlands may be evaluate and managed.

### GEOGRAPHIC LOCATION:

Phase I & III will occur in the two components of the Delaware National Estuarine Research Reserve, and the National Estuary Program, Center for the Inland Bays. Phase II & IV will occur in tidal marshes along the Delaware Bay Coast and inland bays.

### OUTCOME:

Phase I will develop a marsh vulnerability index for *Spartina alterniflora* at three test sites located within the Delaware National Estuarine Research Reserve and the National Estuary Program's Center for the Inland Bays. These three target sites encompass all three counties and three different salinity regimes. This phase will use GIS data, aerial photos, LiDAR data and the Statewide Wetland Mapping Program data along with field validation to develop a *Spartina alterniflora* tidal growth range. These site specific values will be compared with the other regions and values the literature to determine if a Statewide or regional Marsh Vulnerability Index can be developed for

*Spartina alterniflora* marshes. Individual marsh polygon elevations will then be compared with the Marsh Vulnerability Index to estimate the sustainability of that particular marsh.

Phase II will develop a statewide Marsh Vulnerability Index for *Spartina alterniflora* marshes. Contiguous areas of *Spartina alterniflora* will be identified using SWMP data and ArcGIS polygons will be created. Marsh elevation and tidal ranges and mean tide elevations will be determined from the LiDAR dataset and/or additional on the ground sampling. Based on the maximum/minimum elevations derived from the Arc/GIS analysis a refined *Spartina alterniflora* tidal growth range will be developed. The *Spartina alterniflora* marshes throughout the State will then be classified using the Marsh Vulnerability Index. The outcome of Phase II is contingent upon Phase I and a positive index created for *Spartina alterniflora*.

Phase III will develop a marsh vulnerability index for other vegetation types within the same three test sites. Indicator species will be identified that are typically found in other areas of coastal Delaware. These species can be homogeneous communities (species specific index) or common heterogeneous communities (composite index). Based on the maximum/minimum elevations derived from the Arc/GIS analysis, a site specific indicator species composite tidal growth range will be developed. These site specific values will be compared with the other regions to determine if a Statewide or regional composite Marsh Vulnerability Index can be developed for marshes dominated by certain indicator species. The individual marsh polygon elevations will be compared with the Marsh Vulnerability Index to estimate the sustainability of that particular marsh.

Phase IV will produce a Statewide Marsh Vulnerability Index for several indicator marshes throughout the State. Contiguous areas of indicator marshes along the Delaware Coast will be identified and these areas will be defined as polygons in Arc/GIS. A random sampling of the sites will be done to insure the proper identification of the species. Mean, median, maximum and minimum elevations will be determined for each marsh polygon, and actual marsh elevation will be determined with LiDAR data. Additional field sampling may be conducted to verify elevations. The tidal ranges and mean tide elevation will be determined for a range of regions along the Delaware Bay coast. Based on the maximum/minimum elevations derived from the Arc/GIS analysis, a refined indicator species tidal growth range (both species specific and composite indexes) will be developed. The indicator species in marshes throughout the State will then be classified based on marsh species structure, larger contiguous marshes will then be classified using the Marsh Vulnerability Index. The outcome of Phase IV is contingent upon Phase I and a positive index created for *Spartina alterniflora*.

#### ACTIVITIES/SCHEDULE:

1. *Phase I:* Develop *Spartina alterniflora* index for DNERR and CIB locations.
2. *Phase II:* Develop *Spartina alterniflora* index for coastal Delaware locations.
3. *Phase III:* Develop multiple species indexes for DNERR and CIB locations.
4. *Phase IV:* Develop multiple species indexes for coastal Delaware locations

<b>Activity</b>	<b># months req' for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	12	December 2010	Fieldwork Complete/ Processing In Progress
<b>2</b>	12	December 2011	In Progress
<b>3</b>	12	March 2012	Pending
<b>4</b>	12	March 2013	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS (Coastal Delaware Refuge Complex)

University of Delaware

## PRIME HOOK NWR SALINITY/NUTRIENT/SEDIMENT/WATER LEVEL STUDY

Coastal areas and natural resources are particularly vulnerable to climate change, especially with respect to accelerated sea level rise, shoreline erosion, increased storm frequency and intensity, changes in rainfall, and related flooding among other potential impacts. Investigation of such impacts, specifically salinity changes, nutrient inputs and sediment transport within the coastal impoundments at Prime Hook, will be conducted to determine the consequences of management practices and natural events.

Data collection will involve installing monitoring equipment to measure salinity and water level, and conducting salinity transects within the impoundments. Water quality will also be monitored, specifically total sediment solids (TSS) and nitrogen/phosphorus compounds to aid in determining sediment and nutrient fluxes in and out of the impoundments.

### GEOGRAPHIC LOCATION:

Prime Hook National Wildlife Refuge.

### OUTCOME:

This study will result in installation of real-time monitoring network; written reports that include summary of results; discussion of data analysis and statistical procedures. Results will be used to quantify current conditions in the impoundments and predict future changes of future management techniques.

### ACTIVITIES/SCHEDULE:

4. *Installation of monitoring equipment:* Install 7 water level and salinity recorders and set up real-time network
5. *Perform salinity transects:* Perform a series of salinity transects within impoundments II & III
6. *Collection of nutrient and sediment data:* Purchase of sampling equipment, design sampling protocols and collect data for seasonal baseline and storm conditions.
7. *Analyze data and write reports:* Data collected will be analyzed and interpreted leading to an interim reports. These report will be used as a basis for a more detailed study and support management efforts of the Refuge

Activity	# months req'd for completion	Estimated Completion Date	Status
1	2	Oct 2010	Completed
2	24	Oct 2012	Ongoing
3	24	Dec 2012	Pending
4	NA	Ongoing	Ongoing

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

USFWS

## SEDIMENT ELEVATION TABLES

Sediment elevation tables (SETs) provide a nondestructive method for making highly accurate and precise measurements of sediment elevation in intertidal and subtidal wetlands over long periods of time, relative to a fixed subsurface datum. Data collected using SETs can be used to determine both the influence of a single meteorological event on sediment surface elevation and a long-term trend in elevation change. This information will help increase our understanding of sedimentation rates in different marshes, sea level rise effects in these marshes, and potential management techniques.

This project will continue to collect data from established SETs within the St. Jones and Blackbird Creek estuaries. These SETs have datasets that began in 2004-2005 for Blackbird Creek and 2004 and 2007 for St. Jones River. The datasets contain total surface elevation change, shallow surface elevation change, sedimentation, deep subsidence, and shallow subsidence trends.

Marsh surface elevation changes are not merely being controlled by sediment deposition or erosion; subsurface processes are playing a major role in controlling elevation. Separating the influences of the biological (root growth), geological (soil compaction) and hydrological processes (groundwater storage) can be very difficult at best. Measurements from the deep benchmark will document and illustrate the effect that subsidence and compaction (the consolidation and dewatering of the fine grained material deep in the marsh sediments) are having on marsh surface elevation, with these changes in the zone of deep subsidence. The shallow benchmark will localize the effects that occur in the root zone (from the surface to ~ 30 to 50 cm below the sediment surface), such as enhanced growth due to nutrient fluxes, decomposition, compaction, dewatering, and pore water fluxes. Thus, it can be determined whether the subsurface influences are occurring (in the root zone or at deeper depths) and make a first approximation of which processes are dominating elevation change.

### GEOGRAPHIC LOCATION:

The project will be conducted within the St. Jones Estuary in Kent County, Delaware and the Blackbird Creek Estuary in New Castle County, Delaware.

### OUTCOME:

This study will result in a written report that includes a summary of results, discussion of data analysis and statistical procedures. Results can then be used to determine both the influence of a single meteorological event on sediment surface elevation and a long-term trend (i.e. decades) in elevation change, as well as make predictions for future elevation changes in our local marshes.

### ACTIVITIES/SCHEDULE:

1. *SET Monitoring:* SETs will be monitored and read in the St. Jones and Blackbird watershed every 3 months, approximately at the end of each season (i.e. fall, winter, etc.) on the same lunar cycle. Readings will take a total of 6 days per monitoring cycle (3 days each for the St. Jones and Blackbird), for a total of 24 field days for the year. Winter readings could be skipped due to high ice volumes on the marsh surface, which negate the ability to reliably measure the marsh surface.
2. *Status and Trends Report:* A status and trends report of the SET data will be drafted and peer reviewed every two years, for both the St. Jones and Blackbird SET networks. The first report will be completed by February 2011. The report will also include a gap analysis on the current coverage of SET networks across the state and highlight the gaps in spatial

distribution, and make recommendations for future SET placements that could help increase the wetland monitoring.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	On going	Expected 15 to 20 year data set (2019)	On going
2	2	First report, February 2011	On going

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

DNREC Watershed Assessment

Center for the Inland Bays

## IMPLEMENTATION ACTIONS

### CITY OF NEW CASTLE COASTAL RESILIENCY PROJECT

This project is designed to assist the community of the City of New Castle, Delaware in their efforts to reduce hazard vulnerability that currently exists and that could potentially increase in the future due to the impacts of climate change. The City of New Castle currently experiences a number of coastal related problems including; nuisance flooding of streets and road closures due to flooding; storm damage and erosion of dikes; periodic property flooding; and other coastal hazard impacts.

Before communities can develop effective hazard mitigation strategies, they must first identify their hazard risks and assess their vulnerability to the impacts of those hazards. This project will conduct a community-wide vulnerability assessment with broad community involvement and engagement. This will result in an action plan of prioritized projects designed to make the community more resilient, or at a minimum be prepared to recover, from damages associated with coastal hazards.

#### GEOGRAPHIC LOCATION:

City of New Castle

#### OUTCOME:

The goal of this project is to develop a community-wide action plan that increases the resiliency of the City of New Castle, Delaware to the current and future affects of coastal storms and climate change. The project will develop a proactive plan that outlines the specific vulnerabilities of the community and the best actions to be pursued to address these issues. This will include actions to address current risks as well as future risks associated with climate change, including the potential impacts of sea level rise, increased storm frequencies and intensities, tidegate and dike problems or failures, wetland loss, and other impacts.

#### ACTIVITIES/SCHEDULE:

1. *Data Collection and Synthesis:* DCP has submitted a Request for Qualifications (RFQ) in search of firms that will assist in collecting data on the existing tide gates and dikes. More specifically, the selected firm will:
  - a. Perform dike breach analysis and prepare inundation mapping for selected dikes around the City of New Castle
  - b. Perform tide gate analysis including functionality with anticipated sea level rise.
  - c. Prepare Emergency Action Plans for selected dikes around the City of New Castle.
  - d. Prepare Operation and Maintenance Manuals for dikes and tide gates around the City of New Castle.
  - e. Provide engineering support services to the Department as requested in response to dike-related incidents and emergencies including post-incident tasks such as data collection, review and assessment of structures and facilities, and assisting the Department or City of New Castle with planning, designing, and implementing dike repairs.

In addition, existing information will be analyzed and disseminated to provide a factual context to community members about their current storm flooding risk and vulnerabilities.

2. *Vulnerability Assessment:* Conduct a more detailed vulnerability assessment to be used as a guide for developing mitigation strategies and prioritizing mitigation projects.
3. *Strategy Development:* Utilize the detailed results of the vulnerability assessment to develop a final prioritization of needs and a set of strategies to address these needs.
4. *Action Plan Implementation:* A longer term effort to implement the action plan with short term assistance from DCP.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Data Collection and Synthesis</b>		October 2010	Dike Evaluation and Maintenance Plan preparation in progress
<b>Vulnerability Assessment</b>	-----	Summer 2011	In progress
<b>Strategy Development</b>	-----	Summer 2011	Developing workgroup for implementation planning
<b>Action Plan Implementation</b>	-----	Summer 2011	Not Started

#### AGENCIES INVOLVED:

DNREC Division of Watershed Stewardship

DNREC Division of Fish and Wildlife

Delaware Emergency Management Agency

New Castle County Emergency Management

Federal Emergency Management Agency

Delaware Department of Transportation

UD Sea Grant

City of New Castle

## DEVELOPMENT OF A COASTAL FLOOD MONITORING SYSTEM FOR DELAWARE

In the last two decades, storms such as Hurricanes Katrina and Ike along the Gulf of Mexico and Floyd and Hugo along the Atlantic Coast of the United States have resulted in significant loss of life, injuries and property damages reaching well over 100 billion dollars. Much of the damage associated with these and other tropical and extra-tropical weather systems is associated with severe coastal flooding. The Delaware coastline is extremely vulnerable to such events, examples being the great March 1962 storm and the recent coastal flooding incident of May 12, 2008 which left at least one person dead and many homeless after ocean flood waters destroyed homes, especially along the Delaware Bay Coast of Kent County. The added concern of sea-level rise and its effect on the frequency and intensity of coastal flooding events, further emphasizes the need for a modern, dependable coastal flood monitoring system for Delaware's coastal communities.

This project will develop a real-time coastal flood monitoring and warning system for the coastal communities within Kent County, Delaware. This system will serve as a prototype for similar protection along the entire Delaware coast. We will build on the existing competencies of the Delaware Environmental Observing System (DEOS) and the Delaware Geological Survey (DGS) in the development of this prototype system. The deliverables from this project will directly impact several State agencies including the Delaware Department of Natural Resources and Environmental Control (DNREC), the Delaware Emergency Management Agency (DEMA), the Delaware Department of Transportation (DelDOT) and the Delaware National Estuarine Research Reserve (DNERR). Moreover, the proposed system will have a direct impact upon the safety and well-being of Delaware's coastal communities. The system will allow State constituencies to be informed as to tidal conditions and possible flooding situations up to 120-hours in advance of their occurrence. Moreover, the system will indicate those areas that are most likely to be affected by any tidal flooding (roadways, facilities, homes, etc.) allowing for immediate response by appropriate State and County agencies.

### GEOGRAPHIC LOCATION:

Coastal Kent County Delaware

### OUTCOME:

When complete, DEOS and DGS observation sites will continuously monitor environmental conditions across the Delmarva Peninsula. The DEOS will also ingest forecasted tidal levels, based upon astronomical and meteorological conditions, provided through NOAA. When a forecasted (or real-time) critical tidal level is reached, the DEOS ALERTS system will send a message to all interested State officials warning that a coastal flooding situation is possible, which will prompt them to go to the Coastal Flood Monitoring web page. The web page will contain pertinent real-time and forecasted tidal and meteorological information as well as flood inundation maps for each major coastal community along the Kent County coast. Maps will be produced at appropriate flood levels using the latest LIDAR elevation data. Both paper (for dissemination to State and County agencies) and digital (for inclusion on the Coastal Flood Monitoring web page) maps will be produced.

Development of the system will proceed in tandem with the completion of the coastal monitoring GAP Analysis and the inland flood inundation survey. The GAP Analysis will both inform and be informed by the coastal flood monitoring system development. The survey of high water marks during previous coastal flooding events will be conducted using standard surveying techniques by the Delaware Geological Survey. High water marks will be identified, their history confirmed and

the inundation level recorded. This data will be used in conjunction with observed tide heights at USGS tidal monitoring points to better understand the inland inundation associated with various tidal levels along the coast. The association between tide levels at current coastal monitoring sites and inland flood levels is critical in developing statistical relationships that can be used in the development of a coastal flood model that accurately depicts possible inland flooding given a prediction of tidal anomalies at current monitoring sites.

#### ACTIVITIES/SCHEDULE:

1. *Data Collection & Database Modification:* Perform coastal flood inundation surveys, integration of “forecast” data into DEOS data base structure, initial production of flood inundation maps for coastal communities, modification of DEOS ALERTS system for forecast data.
2. *System Integration, Testing & Implementation:* Completion of flood inundation maps, testing of DEOS ALERTS system with forecasted data, development of Coastal Flood Monitoring web page, development of prototype coastal flood statistical model, implementation of system and final report of the project to be presented to DNREC.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	6	January 2010	Completed
2	9	October 2010	Completed

The website for the Coastal Flood Warning System can be found linked to the DEOS website at: <http://www.deos.udel.edu/index.html>

#### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware, Dept of Geography

Delaware Geological Survey

University of Delaware EPSCOR

## DEVELOPMENT OF A COASTAL RESILIENCY ACTION PLAN FOR BOWERS BEACH

Bowers Beach, Delaware is a small Bayfront community in Kent County located between the St. Jones and the Murderkill River. This small town is home to a small commercial fishing fleet and is a popular place for recreational boaters. Although its location makes it attractive for waterfront living and recreating, its location also makes the Town particularly vulnerable to the effects of coastal storms and sea level rise.

This project is designed to assist the community of Bowers Beach, Delaware in their efforts to reduce coastal hazard vulnerability that currently exists and that could potentially increase in the future due to the impacts of sea level rise. Bowers Beach currently experiences a number of coastal related problems including nuisance flooding of streets, episodic storm damage, coastal erosion, and other coastal hazard impacts.

The goal of this project is to develop a community-wide action plan that increases the resiliency of Bowers Beach, Delaware to the current and future effects of coastal storms and seal level rise. The project will develop a proactive plan that outlines the specific vulnerabilities of the community and the best actions to be pursued to address these issues. This will include actions to address current risks as well as future risks associated with climate change, including the potential impacts of sea level rise, increased storm frequencies and intensities, increased rates of erosion, salt water intrusion, wetland loss, and other impacts.

### GEOGRAPHIC LOCATION:

Town of Bowers Beach, Kent County, Delaware.

### OUTCOME:

The final outcome will be an action plan of prioritized projects designed to make the community more resilient, or at a minimum be prepared to recover, from damages associated with coastal hazards. The Town will also acquire the skills necessary to identify and seek out funding opportunities to finance project implementation.

### ACTIVITIES/SCHEDULE:

1. *Phase I-Data Collection and Synthesis:* This first phase of the project will include the collection, analysis, and dissemination of existing information to provide information to community members about their current storm flooding risk and vulnerabilities.
2. *Phase II-Vulnerability Assessment:* Phase two will include a detailed workshop(s) to gather further information and to conduct a detailed vulnerability assessment to be used as a guide for developing mitigation strategies and prioritizing mitigation projects. A Hazards Characterization workshop was conducted to collect the personal experiences from coastal storm and flooding events from the town residents, as well as to identify their initial concerns relating to these storm events. The information gathered during this workshop will be used by a technical workgroup, comprised of State and County experts in project planning and hazard preparations and town representatives, for development of a formal vulnerability assessment and initial mitigation strategy.

3. *Phase III-Strategy Development:* Phase three will utilize the detailed results of the vulnerability assessment to develop a final prioritization of needs and a set of strategies to address these needs.
4. *Phase IV-Implementation:* This phase will be a longer term effort to implement the action plan. Delaware Coastal Programs will take on an advisory role in assisting the town with procuring funding, project design and tracking.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Phase I</b>	9	Winter 2010	Drainage Study ongoing; project webpage published
<b>Phase II</b>	9	Winter 2010	Hazard Workshop conducted and summary document completed;  Assessment workshop conducted; Assessment workshop evaluation ongoing.
<b>Phase III</b>	9	Winter 2010 Spring 2011	-----
<b>Phase IV</b>	12	Spring 2011	-----

**AGENCIES INVOLVED:**

Town of Bowers Beach

Division of Watershed Stewardship -Shoreline and Waterway Management Section and Drainage Section

Delaware Emergency Management Agency

Kent County Emergency Management

Federal Emergency Management Agency

Delaware Department of Transportation

UD Sea Grant

## POLICY DEVELOPMENT

### DEVELOPMENT OF A STATEWIDE SEA LEVEL RISE ADAPTATION PLAN

Sea level rise will have economic, social and environmental effects throughout the State of Delaware. Sea level rise increases the height of storm waves, making more areas vulnerable to storm damage and can inundate low lying areas, causing losses to tidal wetlands, habitat, and agricultural areas. Sea level rise also can cause higher water tables and salt water intrusion, interfering with the septic systems, drinking water and irrigation water. These effects have implications for coastal access and recreation, transportation networks, public safety and land use patterns.

To address these issues, the Delaware Coastal Programs will develop a Statewide Adaptation Plan for Sea Level Rise. Using the data and information collected from other parts of the Sea Level Rise Initiative in combination with the expertise of many other agencies, the adaptation plan will recommend policy changes and practices that will ensure that Delaware makes informed policy and investment decisions today to prevent damage and losses to infrastructure, resources and homes tomorrow. Recommendations will be based upon a careful assessment of potential effects to landowners, communities, economies, natural resources and infrastructure using the best available science and technology.

Development of the Sea Level Rise Adaptation Plan will be guided by an Advisory Committee that is comprised of representatives from state agencies, municipal governments, business and development advocacy groups and environmental advocacy groups. Significant opportunities for public involvement will also be integral to the development of the plan.

#### GEOGRAPHIC LOCATION:

This project will be statewide.

#### OUTCOMES:

The final outcome of this project will be the publication of a Statewide Sea Level Rise Adaptation Strategy that will outline recommended policies and management strategies to reduce the State's vulnerability to the impacts of Sea Level Rise.

Additional outcomes will include:

- Proceedings Document: Sea Level Rise Issues Characterization Workshop
- Statewide Assessment of Delaware's Vulnerability to Sea Level Rise
- Proceedings Document: Sea Level Rise Adaptation Strategies Workshop
- Increased awareness of the impacts of Sea Level Rise at the state and local level
- Increased interagency coordination on Sea Level Rise issues
- Public outreach
- Implementation of strategies

#### ACTIVITIES/SCHEDULE:

1. *Initial Issues Characterization Workshop:* One-day workshop to begin discussing and outlining potential impacts of sea level rise in Delaware. This workshop was held in March, 2009.
2. *Formation of Advisory Committee:* Agencies and organizations will be invited to participate in the Sea Level Rise Advisory Committee and monthly meetings will convene.
3. *Vulnerability Assessment:* Advisory Committee and Delaware Coastal Programs staff will conduct a statewide screening assessment of Delaware's potential vulnerability to sea level rise.
4. *Strategy Development:* Recommendations for strategies to reduce Delaware's future vulnerability to sea level rise will be drafted by the Advisory Committee and during a public workshop. These strategies will be refined and made available to the public for comment prior to finalizing the document.
5. *Implementation of Priority Strategies:* Strategies will be ranked by the Advisory Committee. Funding and other resources will be sought to implement priority strategies.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	2	March 2009	Completed
2	2	November 2010	Underway
3	6	February 2011	Underway
4	8	October 2011	Not yet begun
5	**	**	Not yet begun

\*\* Implementation will be an on-going task with no certain end date

#### AGENCIES INVOLVED:

The following agencies and organizations were invited to participate in the Advisory Committee:

Delaware Department of Agriculture

Delaware Department of Health and Social Services

Delaware Department of Natural Resources and Environmental Control

Delaware Department of Transportation

Delaware Department of Safety and Homeland Security

Delaware Economic Development Office

Delaware Farm Bureau  
Delaware Insurance Office  
Delaware League of Women Voters  
Delaware Nature Society  
Delaware Office of Management and Budget  
Delaware Office of the Governor  
Delaware Realtors Association  
Delaware State Chamber of Commerce  
Home Builders Association of Delaware  
The Nature Conservancy, Delaware Chapter  
Positive Growth Alliance  
Tidewater Utilities, Inc.  
University of Delaware College of Earth Ocean and the Environment

## MID-ATLANTIC REGIONAL COUNCIL ON THE OCEANS (MARCO)

In June 2009 the Governors of Delaware, Maryland, New Jersey, New York, and Virginia convened a summit to mark the signing of the *Mid-Atlantic Governors' Agreement on Ocean Conservation* and the establishment of the Mid-Atlantic Regional Council on the Ocean (MARCO). Discussions held at the Governors Summit built on expert knowledge and led to the identification of initial actions that advance each of the Governors' four shared priorities. Under the MARCO umbrella the five states are working together to address the four priority issue areas which include: protection of sensitive and unique offshore habitat areas; support for the sustainable development of offshore renewable energy; prepare the region's coastal communities for the impacts of climate change on ocean and coastal resources; and promote improvements in the region's coastal water quality. MARCO has recently added a fifth priority to address coastal and marine spatial planning (CMSP) in light of the President's Ocean Policy Task Force recommendations to develop a national framework for CMSP. CMSP is seen by MARCO as a means to advance most, if not all, of the four priorities and each state is taking steps to aid in the development, coordination, and integration of coastal and marine spatial plans for the region.

The Governors Agreement also called for MARCO to hold a Stakeholder Workshop on the initial action plan. In December 2009, key state and federal agency representatives along with high-profile leaders of the full range of ocean interests learned from each other, deliberated, and made commitments to advancing MARCO's shared actions on its priority areas. Based on the valuable feedback and dialogue from the stakeholder workshop, MARCO is collaborating with federal partners to implement the priority actions and is drafting an updated action plan. The DCP hosted two two-day MARCO working meetings in May and August 2010 to further the state-federal partnerships and the updated action plan.

More information can be found on the MARCO website: [www.midatlanticocean.org](http://www.midatlanticocean.org).

### GEOGRAPHIC LOCATION:

Mid-Atlantic region, including the states of Delaware, New York, New Jersey, Maryland, and Virginia.

### OUTCOME:

MARCO will result in improved management of Mid-Atlantic coastal and ocean resources. The collaborative effort will improve outcomes by instituting a regional, ecosystem-based approach and will foster a cooperative and constructive relationship among the states. It will also provide leverage for greater federal investment and action on the states' coastal and ocean management priorities.

### ACTIVITIES/SCHEDULE:

1. *Refine action plan and implement recommendations:* The action plan will be refined based upon the results of the December 2009 stakeholder workshop, the Presidents' Ocean Policy Task Force recommendations and National Ocean Policy, and the recent two day workshop with federal representatives held in August 2010. The plan outlines the goals, specific objectives, and initial actions for each of the four priority areas. Each initial action specifies which state will take the lead on it, which objective(s) it advances, and a proposed timeframe or completion date.

2. *Working Meetings:* The DCP will host and/or attend quarterly/triannual MARCO working meetings for both state and federal representatives.
3. *Stakeholder Engagement:* MARCO is in the process of applying for Federal grant funds to help organize and facilitate stakeholder engagement workshop(s).
4. *ELI Policy Review:* The DCP has contracted with the Environmental Law Institute (ELI) to conduct a detailed review and assessment of the laws, policies, and programs related to offshore renewable energy development activities in the Mid-Atlantic states coastal zones and adjacent federal waters. This will focus on Delaware, but also include information from the other five MARCO states. ELI began work in September 2010 and is on schedule to complete by April 2011.
5. *Regional SLR Adaptation:* The DCP is the lead on addressing MARCO's goal of preparing the region for sea level rise impacts on regional infrastructure, coastal habitat, and shoreline management. DCP will guide the development of vulnerability assessments and sea level rise scenarios for the MARCO region and to promote regional information exchange about adaptation across the states.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	12	June 2011	In progress
2	12	October 2011	In progress
3	24	October 2012	Not yet initiated
4	6	March 2011	In progress
5	2	October 2012	In progress

**AGENCIES INVOLVED:**

States of Delaware, New York, New Jersey, Maryland, and Virginia

## SUSTAINABLE COASTAL COMMUNITIES

Most land use decisions in Delaware are made at the local level, yet those making decisions often lack technical expertise and/or planning resources. To address the lack of technical and planning resources, the Delaware Coastal Programs offers grants and technical assistance to local governments, state agencies and not-for-profit organizations for planning, natural resource management and coastal hazard mitigation.

In previous years, this funding and technical assistance has helped communities develop ordinances, incorporate natural resource considerations into comprehensive land use plans, inventory natural resources and restore important coastal habitats. In 2009 and beyond, the grant program will be more focused towards assisting community planning for reducing impacts resulting from coastal hazards and assessing vulnerabilities and risks to plan for future impacts of sea level rise.

### GEOGRAPHIC LOCATION:

Grants will be available Statewide, through a competitive RFP process.

### OUTCOME:

This program will result in improved management of Delaware's coastal resources through incorporation of coastal hazard and natural resource considerations into local comprehensive plans. This includes coastal storm resiliency planning, development of coastal management ordinances to reduce impacts, and educational outreach for Delaware's local governments.

The DCP anticipates funding and assisting with 3 – 5 projects per year.

### ACTIVITIES/SCHEDULE:

1. *Release RFP and Award Grants:* The funding will be announced through a “Request for Proposals.” Grant proposals received will be ranked by a committee of resource experts and successful grant applicants will be notified.
2. *Grants Management:* DCP staff will negotiate contracts for each grant recipient and will provide technical assistance until the project has been completed.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	4	December 2010	Underway
2	14	March 2012	Not yet underway

### AGENCIES INVOLVED:

Delaware Coastal Programs

## COMMUNICATION, TRAINING AND PUBLIC INVOLVEMENT

### COMPREHENSIVE MARKETING & OUTREACH STRATEGY FOR SEA LEVEL RISE

In order to effectively communicate to the public and decision maker audiences regarding sea level rise issues, the Delaware Coastal Programs (DCP) established a Sea Level Rise Outreach Strategy Committee comprised of educators, marketers, and communication specialists from the Delaware National Estuarine Research Reserve, Delaware Sea Grant, the Partnership for the Delaware Estuary, DNREC – Public Affairs, DNREC – Shoreline and Waterway Section, in addition to staff from DCP to develop a comprehensive sea level rise marketing and outreach strategy. The strategy provides a clear, coordinated message with information and materials developed and disseminated by all of the organizations of the Committee including Delaware Coastal Programs, Delaware National Estuarine Research Reserve.

As part of the development of this comprehensive strategy, a statewide survey to gauge public knowledge and opinions on sea level rise and its impacts on Delaware was completed in the spring of 2010. This survey provides information about Delaware residents' awareness and understanding of key issues regarding climate change and sea level rise; determine their perception of its overall effect on the economy and ecology of the state; and explore public opinion regarding long range planning for sea level rise loss and damage prevention. Using the results of this survey, as well as other studies and reports focused on improving communications on sea level rise and climate change, a comprehensive marketing and outreach strategy has been drafted to enhance the public and coastal stakeholders' awareness and response to sea level rise.

The strategy considers a variety of audiences (such as local, county, and state government officials, local and regional planners, economic development representatives, agriculture representatives, university researchers, educators, and property owners) and includes workshops, seminars, brochures, factsheets, public service announcements, media buys, website development and/or outreach displays.

#### GEOGRAPHIC LOCATION:

Statewide

#### OUTCOME:

A comprehensive marketing and outreach strategy and an implementation/work plan have been drafted.

#### ACTIVITIES/SCHEDULE:

1. *Strategy Development:* An inventory of existing Sea Level Rise marketing and outreach programs will be completed and will be analyzed along with results of the Sea Level Rise Attitudes and Perception Survey. This analysis will then be interpreted to design a targeted Marketing and Outreach program.
2. *Strategy Implementation:* Activities listed in the strategy will be implemented.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	4	Fall 2010	Draft Completed
<b>2</b>	Ongoing as needed	-	Underway

#### AGENCIES INVOLVED:

##### DNREC

Delaware Coastal Programs

Division of Watershed Stewardship/Shoreline & Waterway Management

Public Affairs

Delaware Sea Grant

Partnership for the Delaware Estuary

Responsive Management

## SEA LEVEL RISE INTERNET MAP VIEWER

Land-use decisions in Delaware are primarily made at the local level yet, often these smaller towns lack the GIS infrastructure that would allow large scale planning efforts, particularly those related to coastal hazards. Delaware Coastal Programs has made significant investment in GIS data, personnel, and hardware over the years. Transferring the benefits of this investment to community decision makers is vital to the success of these planning efforts.

As part of DCP's efforts assisting local governments with Coastal Hazard and Community Resilience Planning, data will be created and shared with the local decision makers and the community. Internet based mapping applications can be a useful tool to affect this sharing. Most local governments and citizens have access to basic internet browsers either at home or in public libraries. Online mapping tools such as Google Maps and Virtual Earth provide free, lightweight mapping tools that members of the public can use to participate in planning efforts. More robust applications, such as ArcGIS Server and Google Earth, allow for more complex views of Community Resiliency information while keeping costs at a minimum (i.e. free to end user). The choice of tool used will depend on the needs of the user and the ability of the tool to present the data.

DCP has utilized ArcGIS Server to produce and distribute Statewide Sea Level Rise Inundation maps for these planning efforts. KML versions of the data are available, however, the datasets are too large to be conveniently accessed on slower internet connections. ArcGIS Server provides both a freely accessible viewer for the general public and advanced access for GIS users to a map service.

### GEOGRAPHIC LOCATION:

Maps of DNEC's Sea Level Rise Inundation Scenarios are available statewide. Distribution of more localized data will initially focus on individual communities undergoing resiliency planning (i.e. Town of Bowers and City of New Castle).

### OUTCOME:

Website(s) providing citizen access to Community Resilience Planning Maps.

<http://www.dnrec.delaware.gov/Pages/SLRMaps.aspx>

### ACTIVITIES/SCHEDULE:

1. *Software needs assessment and acquisition:* Evaluate capabilities of various software to provide mapping data to public through open GIS browsers. Acquire selected software.
2. *Data List:* Develop and initial list of data to be distributed to community members.
3. *Data Conversion:* Convert selected data and maps for distribution.
4. *Website creation:* Establish a new set of pages within DCP's Sea Level Rise web section for distribution of mapping information.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	1 month		Complete
<b>2</b>	1 month		Complete
<b>3</b>	1 month		Complete
<b>4</b>	1 month		Complete

AGENCIES INVOLVED:

Delaware Coastal Programs

DNREC – Office of Information Technology

## STATEWIDE SURVEY TO GAUGE PUBLIC KNOWLEDGE AND OPINIONS ON SEA LEVEL RISE AND ITS IMPACT IN DELAWARE

In order to effectively plan and target sea level rise outreach and technical assistance, it is important to understand the public perception of sea level rise. However, there is currently no statewide information available regarding the level of knowledge Delawareans possess regarding sea level rise and its future impacts; nor whether Delawareans are motivated to change their behaviors to reduce their risk to impacts associated with sea level rise.

In order to address this need, the Delaware Coastal Programs, in cooperation with The Nature Conservancy and with contractual assistance from Responsive Management Inc. conducted a statewide telephone survey during the fall 2009. The survey was designed to be statistically significant and to assess Delaware residents' awareness and understanding of key issues regarding climate change and sea level rise; to determine their perception of its overall effect on the economy and ecology of the state; and to explore public opinion regarding long range planning for sea level rise loss and damage prevention.

The survey was completed in January 2010 and is available for download online:  
<http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/SLRSurveyReport.pdf>

### GEOGRAPHIC LOCATION:

The telephone survey was conducted statewide.

### OUTCOME:

The survey resulted in a written report that includes a summary of results; discussion of data analysis and statistical procedures, a tabular data report, survey graphs and tables, frequency distributions and cross-tabulations. The report has since been used to help in the development of an outreach and marketing strategy, and to guide the content of other outreach and educational products.

### ACTIVITIES/SCHEDULE:

1. *Develop survey instrument:* In cooperation with other interested agencies and Responsive Management, design and test the survey.
2. *Conduct Telephone Survey:* Responsive Management will conduct the phone survey using random dialing.
3. *Analyze Results:* Responsive Management will analyze the results of the survey with appropriate statistical tests.
4. *Prepare Report:* Responsive Management will prepare a final report that provides an executive summary, methodology, data and appropriate charts and graphs.
5. *Distribute and Explain Report:* Final report will be made available via the web and hard copy. Workshops will be held in cooperation with the Nature Conservancy and Responsive Management to explain the results of the survey.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	2	July 2009	Complete
<b>2</b>	2	November 2009	Complete
<b>3</b>	2	December 2009	Complete
<b>4</b>	1	January 2010	Complete
<b>5</b>	6	March 2010	Complete

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

The Nature Conservancy

Responsive Management

PREPARING FOR SEA LEVEL RISE  
DEVELOPMENT OF A SEA LEVEL RISE INITIATIVE

Sea Level Rise Initiative  
Project Compendium  
October 2010



*Photo by: Delaware Shoreline and Waterway Management Section*

*A Compendium of Delaware Coastal Programs' Projects that Address  
Sea Level Rise*



Delaware Coastal Programs

(302) 739-9283



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## THE SEA LEVEL RISE INITIATIVE

In recognition of the importance of the coast to the Nation's commerce, energy development and natural resource protection, the Coastal Zone Act of 1972 was enacted to assist States manage these conflicting uses of coastal areas. At that time, in addition to directing State Coastal Zone Management Programs to address issues of pollution, development, navigation and energy development, the Coastal Zone Act also directed States to prepare for sea level rise.

In recent years, improved climatic and ocean observation systems have made it possible for scientists to better assess the potential for sea level rise and make predictions for the future. These predictions have shown that coastal areas, particularly in the Mid-Atlantic states, will likely see an increased rate of sea level rise. The U.S. Climate Change Science Program's (CCSP) 2009 document, "Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic" recommends that states should prepare for sea level to rise by at least one meter (39 inches) by 2100; the current rate of sea level rise measured by a tide gauge in Lewes Delaware is 13 inches per 100 years. The CCSP prediction is in close agreement with many other predictions by Federal, State and Global agencies and represents a three-fold increase in the historic rate of sea level rise.

This level of sea level rise will have economic, social and environmental effects throughout the State of Delaware. Sea level rise will inundate low lying areas, causing significant losses to tidal wetlands and wildlife habitat. As the high tide line encroaches landward, some important agricultural areas may no longer be suitable for tillage. Sea level rise also can cause higher water tables and salt water intrusion, interfering with the septic systems, drinking water and irrigation water. Most importantly for many coastal communities, sea level rise can increase the effects of storm surge and waves, allowing flooding to occur in areas that may have never previously been susceptible to flooding from storms. All of these potential effects from sea level rise also have implications for coastal access and recreation, transportation networks, public safety and land use patterns.

To help assess, prepare for and minimize the potential impacts of sea level rise, the Delaware Coastal Programs Section of the Delaware Department of Natural Resources and Environmental Control is leading a multi-year Sea Level Rise Initiative. The goal of the Sea Level Rise Initiative is to reduce Delaware's future vulnerability to the effects of sea level rise. This will be accomplished by:

- Providing scientific and technical support for decision-making
- Implementing on-the-ground project in partnership with stakeholders
- Providing educational and outreach opportunities for stakeholders and the public
- Improving existing policies and management practices and/or developing new policies and management practices where necessary

As part of the goal of providing scientific and technical support for decision-making, Delaware Coastal Programs scientists have partnered with the National Wildlife Refuge System, the University of Delaware, local Estuary Programs and other state agencies to fill gaps in our knowledge about coastal storms, tide levels and marsh sediment accretion. This data and information will be used for policy development; communication of this new information is a component of the outreach strategy.

As part of the goal of implementing on the ground projects, Delaware Coastal Programs staff have partnered with the City of New Castle and the Town of Bowers Beach to help them improve their

preparedness for coastal storms and future sea level rise. Related to this effort, and using high resolution elevation data, a real time flood monitoring system is being developed that will greatly improve flood response in coastal communities.

Public involvement and outreach is a critical component of preparing for sea level rise. All of the tools and data developed during the Sea Level Rise initiative will be communicated to the public through websites, presentations, public events, articles and decision-maker workshops. This is detailed in a comprehensive outreach strategy for sea level rise, developed in partnership with the DNREC Watershed Stewardship Division, the Delaware Estuary Program and Delaware Sea Grant.

These projects, along with others described in this document, have been initiated under the Sea Level Rise Initiative to help to build partnerships and capacity, increase resiliency, increase public knowledge of and support for actions to reduce our vulnerability and make decisions based upon the best available science. The Sea Level Rise Initiative is designed to be iterative and will grow and change as new data, outreach and policy needs are identified.

## PURPOSE OF COMPENDIUM OF SEA LEVEL RISE INITIATIVE PROJECTS

The purpose of the Sea Level Rise Initiative Compendium of Projects is to provide an at-a-glance inventory of the projects and initiatives are being conducted as part of the Delaware Coastal Programs' Sea Level Rise Initiative. It is intended to help increase collaboration between agencies, reduce redundancy and overlap in projects relating to sea level rise and to relay information about new (or soon to be available) data, information and tools.

Projects conducted without the assistance or involvement of the Delaware Coastal Programs are not currently reflected in this document. However, there are many other agencies whose work will be essential to preparing for sea level rise and coastal inundation. The Delaware Coastal Programs may in the future consider expanding the scope of this document to include other agencies' work.

Because the projects listed in this document are likely to evolve over time, it is our intent to update this document on a routine basis so that our partner agencies can be kept up to date on sea level rise activities. The most current version of the document will be posted on the Delaware Coastal Programs' sea level rise website.

## FOR MORE INFORMATION

For more information about projects contained within the Sea Level Rise Initiative Compendium, please contact us at (302) 739-9283 or see our website:

<http://www.swc.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx>

## SCIENTIFIC AND TECHNICAL SUPPORT

### BOMBAY HOOK HYDROLOGY/SEDIMENT MOVEMENT STUDY

Coastal areas and natural resources are particularly vulnerable to climate change, especially with respect to accelerated sea level rise, shoreline erosion, increased storm frequency and intensity, changes in rainfall, and related flooding among other potential impacts. Investigation of such impacts, specifically marsh depletion and increased mudflats at Bombay Hook, will be conducted to determine patterns of sediment flux in or out of the depleted marsh area.

Data collection will involve conducting river transects within the Leipsic River using the Acoustic Doppler Current Profiler (ADCP) and associated software to collect and process tide and current data. Water quality will also be monitored, specifically total sediment solids (TSS) to aid in determining sediment fluxes in or out of the depleted marsh area.

#### GEOGRAPHIC LOCATION:

Bombay Hook National Wildlife Refuge.

#### OUTCOME:

This study will result in a written report that includes a summary of results; discussion of data analysis and statistical procedures. Results will be used to predict future changes in marsh depletion and to help determine marsh management techniques to counteract these impacts affecting the tidal marshes at Bombay Hook.

#### ACTIVITIES/SCHEDULE:

1. *Installation of monitoring equipment:* Install 5 water level recorders and 1 Acoustic Doppler Current Profiler.
2. *Perform cross-section current profiles and collect data:* Perform a series of cross-section current profiles at various locations over varying tidal stages and collect water level and ADCP data.
3. *Analyze data and write report:* Data collected to date will be analyzed and interpreted leading to an interim report. This report can be used as a basis for a more detailed study and support future modeling efforts in the Refuge

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	1	May 2009	Completed
<b>2</b>	NA	Ongoing	Ongoing
<b>3</b>	3	March 2011	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS

## COASTAL IMPOUNDMENT ACCRETION RATE STUDY

As an accelerated rate of relative sea-level rise further stresses impounded marshes, there is a greater need to evaluate the long-term sustainability and utility of impoundments in Delaware. In order to do this, baseline data regarding historic sedimentation rates is needed.

Baseline data sets of long-term sedimentation rates in impounded and natural wetlands can be utilized to evaluate the impounded wetlands' ability to achieve optimal habitat benefit under different management strategies and under different sea level rise scenarios

Long-term sedimentation rates over the past 100 and 50 years can be calculated by collecting radioisotopic cores from wetland areas and analyzing them for  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$ . All core sites and the adjacent wetland will be surveyed to tie all data to the tidal datum (NAVD 88). Correlating long-term wetland sedimentation rates to current wetland elevation will enable a detailed analysis of the potential sedimentation deficits that exist within the impoundments, as compared to the reference wetlands. The elevation and sedimentation gradients between the reference and impounded wetlands can be used to calculate potential future elevation trajectories under different sea-level rise and management scenarios.

### GEOGRAPHIC LOCATION:

Monitoring sites were chosen within impounded and reference (natural marsh) sites throughout the State based upon a wetland area change analysis (using a time-series of available imagery), and basins that have been identified as needing detailed study to aid in their management to optimize the future available habitat. Sites that will be studied include: marshes along the Delaware River near New Castle; Ted Harvey Wildlife Area; St. Augustine Wildlife Area; and Primehook National Wildlife Refuge.

### OUTCOME:

When complete, this study will provide information to coastal managers regarding marsh susceptibility to sea level rise under different marsh management scenarios and under different sea level rise scenarios. A long-term comparison of the wetland elevation and sedimentation conditions between the impounded marsh and the "natural" marsh will enable a detailed analysis and comparison of the potential long-term growth conditions and highlight the potential implications for impoundment management that could affect the sustainability of the interior wetlands. This information will allow marsh managers to understand the potential outcomes of sea level rise and adapt their management techniques.

### ACTIVITIES/SCHEDULE:

1. *Initial Impoundment Core Collection:* Radioisotopic cores will be collected from selected marshes. All core sites and adjacent wetlands will be surveyed. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis is scheduled to be complete by December 2009.
2. *New Castle Impoundment Core Collection:* Radioisotopic cores will be collected from 3 impoundments and 2 reference marshes along the Delaware River adjacent to the City of New Castle. All core sites and adjacent wetlands will be surveyed after collection. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis is expected to be complete by December 2010.

3. *Kent County and Lower New Castle County Impoundment Core Collection:* Radioisotopic cores will be collected from Ted Harvey Wildlife Area, St. Augustine Wildlife Area, and Primehook National Wildlife Refuge. The Ted Harvey and St. Augustine sites were selected to expand the scope of the impoundment investigation to include sites along the entire Bay and River coast. All core sites and adjacent wetlands will be surveyed after collection. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis by UD is expected to be completed by December 2011.
4. *Gap Analysis of Delaware Coast:* A gap analysis of the Delaware River and Bay Coast Impoundments and reference marshes will be conducted to identify areas where additional cores should be collected and analyzed. The previously analyzed cores will be examined to evaluate the spatial and temporal variability within the study areas and evaluate the need for additional coring sites. A total of 18 cores will be collected to fill in the identified data gaps and areas of high spatial sedimentation rate variability.

<u>Activity</u>	<u># months req'd for completion</u>	<u>Activity Start Date</u>	<u>Estimated DCP Completion Date</u>	<u>Estimated Laboratory Completion</u>	<u>Status</u>
1	5	November 2008	March 2009	April 2010	In Progress
2	8 - 10	April 2009	November 2009	December 2010	In progress
3	6	December 2009	May 2010	December 2011	Pending
4	8	May 2010	January 2011	December 2012	Pending

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

UD College of Earth, Ocean and Environment

Primehook National Wildlife Refuge (USFWS)

DNREC Division of Fish and Wildlife

## COASTAL MONITORING GAP ANALYSIS

In the last two decades, storms such as Hurricanes Katrina and Ike along the Gulf of Mexico and Floyd and Hugo along the Atlantic Coast of the United States have resulted in significant loss of life, injuries and property damages reaching well over 100 billion dollars. Much of the damage associated with these and other tropical and extra-tropical weather systems is associated with severe coastal flooding. The Delaware coastline is extremely vulnerable to such events, examples being the great March, 1962 storm and the recent coastal flooding incident of May 12, 2008.

As part of a cooperative effort between the University of Delaware and several Delaware State Agencies to better monitor conditions along the Delaware coastline and to provide advance warning of impending coastal flooding events, we propose the completion of a GAP Analysis of pertinent coastal data needs and a comprehensive survey of inland inundation levels during previous coastal flooding events. The GAP Analysis will define the present state of coastal data collection efforts across the state, an “optimum” data collection network and the gap between them, indicating those data that need to be added to the current network. A survey of high water marks from previous coastal flooding events will be used to create a “baseline” data set to aid in understanding the relationships between water levels at tidal monitoring points and inland locations. In this research, an exhaustive inventory of real-time and archived coastal data will be conducted. This inventory will include meteorological, tidal, buoy, water quality and inundation data sources, along with ancillary sources of coastal information (i.e. research publications, modeling work, etc.).

### GEOGRAPHIC LOCATION:

Coastal Delaware.

### OUTCOME:

The final outcome/product will be a report that makes recommendations as to the type of data needed to reach an “optimum” coastal monitoring network, and the spatial placement and temporal resolution of additional sensors that may need to be deployed to reach the optimum configuration. The report is available at:

[http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Gap\\_Analysis\\_Final\\_Report\\_032910.pdf](http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Gap_Analysis_Final_Report_032910.pdf) or <http://www.deos.udel.edu/delawaregap/index.html>

### ACTIVITIES/SCHEDULE:

1. *GAP Analysis Report:* University of Delaware will conduct the analysis and develop a report that makes recommendations as to the type of data needed to reach an “optimum” coastal monitoring network.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	9	March 2010	Completed

### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware

## COASTAL STORM HISTORY

Several coastal communities in Delaware currently experience storm damage, coastal erosion, and other coastal hazard impacts. In efforts to reduce hazard vulnerability that currently exists and that could potentially increase in the future due to climate change impacts, the Delaware Coastal Programs, along with the University of Delaware are compiling data on historical storms, nor'easters, subtropical storms or hurricanes that may have impacted Delaware's coasts in the past.

This data was previously compiled by the University of Delaware for years up through 1974 and a written report is available. This project will focus on updating the storm data from 1974 to 2009.

### GEOGRAPHIC LOCATION:

Coast of Delaware.

### OUTCOME:

Compendium of historical storm data categorized according to the type of storm, physical characteristics and impacts on coastal communities and natural resources. This can perhaps be used to derive specific scenarios to be modeled for the purpose of future adaptation and preparedness. It will also help to identify where outside expertise should be brought in to provide additional technical assistance for resiliency assessment, planning and implementing. Depending on the detail of the data collected, there may be some insight for prediction of the next potential storm, nor'easter or hurricane and the impacts of such events.

### ACTIVITIES/SCHEDULE:

1. *Storm data collection:* Through analysis of historic data sets and communication with local and state officials and the public, historic storm information will be compiled.
2. *Development of Report:* A compilation report will be developed and distributed. The report will include storm data from 1974 to present including all pertinent data.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Contract signed</b>	n/a	Feb 2010	Completed
<b>1</b>	12	Sept 2010	Completed
<b>2</b>	6	March 2011	Pending

### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware

## DEVELOPMENT OF COASTAL INUNDATION MAPS

Sea Level Rise inundation maps are necessary to determine areas and extent of coastal vulnerability to sea level rise, and will be a key component guiding the development of a Statewide Sea Level Rise Adaptation Plan. While it is relatively straight forward to overlay elevated sea level changes onto existing digital elevation models (DEMs), certain factors must be considered. Primarily, mean tide levels vary along the Delaware Bay Coast and any maps developed must take this into consideration. Secondly, solely using sea level rise will not give a true perspective of inundation, since the major concern will be the flooding from coastal storm surges.

To develop these maps (GIS Layers) a statistical evaluation from the existing 2 long-term NOAA tide level datasets of Lewes (Breakwater Harbor) and Delaware City (Reedy Point) will be performed to establish storm surge elevations above Mean Higher High Water (MHHW) for selected return periods (i.e. 10, 25 50, 100-year return periods). Once these are calculated, the current MHHW levels along the length of the coast will be determined using the NOAA VDatum software. These two datasets will be combined to establish the appropriate elevations to use for coastal inundation. After the Delaware Bay coast is completed, a similar effort will be performed for the Inland Bays and Atlantic Coast.

### GEOGRAPHIC LOCATION:

Coastal Delaware

### OUTCOME:

The final outcome/product will be a series of maps in GIS format that will be based on the bare earth LIDAR data. Several scenarios will be developed using on current sea level rise, predicted average sea level rise and predicted maximum sea level rise for the years 2050 and 2100. Estimates of storm surge added to the predicted elevations will also be provided. These surges will be based on historic data and statistical analysis.

### ACTIVITIES/SCHEDULE:

1. *Statistical Analysis of existing tide data:* Based on existing data for Lewes and Delaware City, develop expected storm surge levels for certain return periods.
2. *Determine MHHW for Bay Coast:* Using VDatum, determine MHHW along Delaware Bay coastline corrected to NAVD88
3. *Develop Inundation Maps for Delaware Bay Coast:* Combining the two developed datasets, produce GIS maps for different seal level and storm surge scenarios
4. *Inland Bays and Atlantic Coast Maps:* Repeat 1-3 for Inland Bays and Atlantic Coast.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	<b>2</b>	September, 2009	Completed
<b>2</b>	<1	October, 2009	Completed
<b>3</b>	<b>2</b>	December, 2009	Completed
<b>4</b>	<b>1</b>	January, 2010	Completed

**It is anticipated that all inundation maps will be frequently updated as new information on sea level rise becomes available.**

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

## DIGITAL COAST

The Digital Coast is a nationwide initiative that is designed to ensure the wise use and management of coastal resources by providing coastal managers with data, training, tools and examples to assist them with emerging and priority coastal issues. The partner network identifies Digital Coast priorities and then works together to address coastal issues.

Currently, the Digital Coast partnership is focused on providing data, tools and examples to coastal managers regarding coastal inundation and sea level rise. Projects to address other coastal issues (i.e., marine spatial planning, conservation) will be developed in the future.

One of the goals behind the creation of the Digital Coast was to unify groups that might not otherwise work together and build a strong collaboration of coastal professionals intent on addressing coastal conservation needs. The Digital Coast Partnership Group is currently comprised of representatives from the Association of State Floodplain Managers, the Coastal States Organization, the National Association of Counties, the National States Geographic Information Council, The Nature Conservancy, and the NOAA Coastal Services Center. Delaware Coastal Programs staff has actively served as part of the Coastal States Organization representatives on this project. The National Oceanic and Atmospheric Administration's

(NOAA) Coastal Services Center is the lead organization for Digital Coast efforts.

### OUTCOME:

In the fall of 2009, the Coastal Inundation Toolkit, was released. The toolkit was being developed by the Digital Coast Partnership Group to help communities understand and address coastal inundation issues. Website components include:

- Understand – Learn about inundation basics and common hazard concepts
- Identify – Download the county-specific charts and graphs that tell your story
- Map – Use the steps provided to discover and map areas of potential impact
- Assess – Use inundation maps to assess community risk, vulnerability, and resilience
- Inform – Use risk communication strategies to illicit change
- Discover – See how other communities are addressing this issue

This tool is expected to be of enormous value as a resource tool for the many groups concerned with and working to address coastal flooding and Sea Level Rise issues in Delaware.

Current and future Modules of Digital Coast resources are available at:

<http://www.csc.noaa.gov/digitalcoast/>

## HYDROLOGIC MONITORING OF THE KITTS HUMMOCK AREA

To properly understand the relationships between the Delaware Bay, interior marsh water levels, ponds, impoundments and the drainage ditch network around Kitts Hummock, a comprehensive water level monitoring program will be established. Establishing a water level monitoring network at key locations will aid in the understating the interrelationships between the water bodies and the influence of the drainage network in the community on these water bodies. This baseline monitoring is one of the prerequisite needs for conducting any defensible modeling and evaluation of the effectiveness of any proposed drainage improvements to the Kitts Hummock area. Additional needs prior to modeling include validation of marsh elevations, detailed documentation and assessment of previous storms, and engineering designs of proposed alterations

This baseline network will use a total of 8 Inset HOBO water level recorders in conjunction with the USGS Tide gauge located approximately 5 kilometers south at Bowers Beach and other currently monitored parameters. Two water level recorders will be placed on the north and south sides of Kitts Hummock Road in the primary N/S drainage ditch approximately 250 meters inland from the Delaware Bay. An additional three water level recorders will be used to examine the effects of marsh water elevation and the northern impoundment of the Logan Lane Tract of the Ted Harvey Conservation Area on the open water area of a private property and the South Bay Drive drainage ditch. The final two water level recorders will be installed in open water areas of the marsh northeast of the community of Kitts Hummock to estimate the tidal backwater effects north of Kitts Hummock Road. A final recorder will be housed at the Delaware National Estuarine Research Reserve (DNERR) to measure barometric pressure changes which will be used to atmospherically correct the readings of the water level recorders. The recorders will be surveyed to an accuracy of  $\pm 2$  cm vertical, and maintained and downloaded monthly by staff from the DNERR.

### GEOGRAPHIC LOCATION:

This project encompasses the area surrounding Kitts Hummock, Kent County, DE, including the private marsh lands north and south of the community and the DNREC/DFW Logan Lane Tract of the Ted Harvey Conservation Area.

### OUTCOME:

Once sufficient data has been collected, which includes a minimum of 3 months of data and at least 3 significant storm events, the data will be compiled. Data on rainfall and wave height, period and direction, currently being monitored by the DNERR, will be incorporated into the data set and then the dataset will be analyzed. This analysis will include examining the Bay tide effects on marsh water/drainage ditch elevations; relationships of surrounding water levels on the Thompson open water area; probable pathways of tide related flooding; and a qualitative evaluation of the expected effectiveness of drainage ditches in the area during different tidal cycles/storm events.

### ACTIVITIES/SCHEDULE:

1. *Data Collection:* Install data recorders, survey locations and collect data.
2. *Data Analysis:* Analyze data, run computer simulations, develop qualitative evaluation of storm event drainage scenarios.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	3-5	October 2009	Complete
<b>2</b>	3	December 2009	Complete

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

DNREC Drainage and Stormwater Section

DNREC District Operations

## MARSH LOSS ANALYSIS (INTERIOR OPEN WATER CREATION)

Staff from Bombay Hook NWR contacted the Delaware Coastal Programs for assistance with their 5-year Biologic Review of the refuge. Refuge staff felt that DCP's experience with GIS analysis could help them answer some questions they had about the changing habitat of the refuge. Coastal change, rising sea levels, erosion and land subsidence are increasingly tough issues facing coastal managers, engineers, and planners charged with developing and protecting coastal habitats and communities in vulnerable coastal zones. Understanding these threats depends on early detection, and solutions will require vigorous public debate over engineering solutions vs. strategic retreat. The drastic changes at Bombay Hook National Wildlife Refuge (NWR) may be a harbinger of coast-wide habitat changes in the future.

The coastal areas of Bombay Hook NWR have historically been subjected to significant erosion. Historical shorelines from as far back as 1842 paint a much different picture than exists today. Shores that face the East and Southeast take the worst damage. These areas have the longest fetch allowing the winds to add more power to the waves that break on these shores. For the period 1937-2002, roughly 1700 ft. of erosion occurred along the southern shoreline of Bombay Hook (26 ft/yr). This habitat loss is now coupled with increasing amounts of open water creation in the interior marsh.

Aerial photos from 1979, 1992, and 2002 were examined for expansion of open water areas in the interior marsh. Photos were viewed on a geographic information system and areas of open water were outlined. Results showed that, over the years, open water areas were growing larger and combining together. What had been a mosaic of small areas of open water mixed in vegetated marsh are becoming large tracts of open water with vegetation around the edges. This Study revealed that since 1979, the Refuge has lost a total of 12% of its wetland area; 10% attributed to the creation of interior, open water areas.

No single, direct cause for the wetland loss has yet been identified. Some potential causes including sea level rise, marsh/land subsidence, and snow goose grazing are being looked into. These effects are inter-related and tend to work together to make matters worse. Currently DCP and others are using sediment elevation tables to explore subsidence and sedimentation in regional marshes. It is hoped that if a cause(s) can be determined, adjustments in marsh management can be made to stem the loss of interior area.

This project will investigate the expansion of open water areas in four additional areas throughout the state: the Thousand Acre Marsh region; Blackbird Creek; Milford Neck and Primehook National Wildlife Refuge. For each area, open water areas will be digitized using ArcGIS from historic aerial photographs to determine extent of open water areas over time.

### GEOGRAPHIC LOCATION:

DCP is now expanding the study to other similar marsh areas around the State: 1000 Acre Marsh, Blackbird Creek, Milford Neck Wildlife Area and surrounding private conservation lands; and Prime Hook NWR with nearby areas in Broadkill Beach.

#### OUTCOME:

This project will result in GIS maps of marsh loss over time for the study areas.

It is also hoped that this information can be combined with results from other studies and may shed light on the causes of the wetland loss. This combination of information is expected to lead to management changes that can limit further loss and possibly aid recovery of the marshes.

#### ACTIVITIES/SCHEDULE:

1. *Digitize open water areas:* Bombay Hook.
2. *Digitize open water areas:* 1000 Acre Marsh.
3. *Digitize open water areas:* Blackbird Creek.
4. *Digitize open water areas:* Milford Neck.
5. *Digitize open water areas:* Prime Hook.

Activity	# months req'd for completion	Estimated Completion Date	Status
1.			Complete
2.			Complete
3.			Complete
4.			Complete
5.			Complete

#### AGENCIES INVOLVED:

Delaware Coastal Programs

## MARSH VULNERABILITY INDEX

An index is needed to allow assessment of the long-term viability of Delaware's marshes under differing sea level rise scenarios and to target areas for conservation, restoration and monitoring. The Tidal Marsh Vulnerability Index will be based upon the positive correlation between mean tidal range and elevational growth range of tidal wetland plant species. Biomass sampling, taken from the Mid-Atlantic Wetland Rapid Assessment Method (MidTRAM), will also be incorporated into the Marsh Vulnerability Index to assess marsh health. Once developed, the Sea Level Rise Index for Tidal Marshes tool could be transferred to other states and used for regional comparisons and regional planning.

The Tidal Marsh Vulnerability Index will classify marshes as healthy, degrading or severely degrading. These classifications will be utilized to select areas to conduct detailed sediment accretion rate and other monitoring. Degraded and severely threatened marshes are known to have lower elevations, relative to the tidal prism, and are more prone to catastrophic losses due to sea-level rise and storm events. Understanding the current and historic sedimentation accretion rates of these marshes can help to better predict the longevity and the sediment deficits of these areas and possible management practices that might be implemented to prevent marsh elevation losses (i.e. thin layer application of sediment, vegetation plantings, etc.).

The Tidal Marsh Vulnerability Index, in conjugation with time-series analysis of aerial imagery, will be essential for evaluating wetland vulnerability on a watershed or statewide basis, while enabling the strategic placement of monitoring resources to enhance our efforts to understand the future evolution potential of Delaware's tidal wetlands. All field based monitoring and sampling efforts can be initiated and implemented to evaluate the most severely threatened marsh areas first; the monitoring can then be expanded to encompass other marsh regions as resources become available. Marsh Vulnerability Index classification optimizes the monitoring efforts and resources to the highest levels possible, so the broadest extent of Delaware's tidal wetlands may be evaluate and managed.

### GEOGRAPHIC LOCATION:

Phase I & III will occur in the two components of the Delaware National Estuarine Research Reserve, and the National Estuary Program, Center for the Inland Bays. Phase II & IV will occur in tidal marshes along the Delaware Bay Coast and inland bays.

### OUTCOME:

Phase I will develop a marsh vulnerability index for *Spartina alterniflora* at three test sites located within the Delaware National Estuarine Research Reserve and the National Estuary Program's Center for the Inland Bays. These three target sites encompass all three counties and three different salinity regimes. This phase will use GIS data, aerial photos, LiDAR data and the Statewide Wetland Mapping Program data along with field validation to develop a *Spartina alterniflora* tidal growth range. These site specific values will be compared with the other regions and values the literature to determine if a Statewide or regional Marsh Vulnerability Index can be developed for

*Spartina alterniflora* marshes. Individual marsh polygon elevations will then be compared with the Marsh Vulnerability Index to estimate the sustainability of that particular marsh.

Phase II will develop a statewide Marsh Vulnerability Index for *Spartina alterniflora* marshes. Contiguous areas of *Spartina alterniflora* will be identified using SWMP data and ArcGIS polygons will be created. Marsh elevation and tidal ranges and mean tide elevations will be determined from the LiDAR dataset and/or additional on the ground sampling. Based on the maximum/minimum elevations derived from the Arc/GIS analysis a refined *Spartina alterniflora* tidal growth range will be developed. The *Spartina alterniflora* marshes throughout the State will then be classified using the Marsh Vulnerability Index. The outcome of Phase II is contingent upon Phase I and a positive index created for *Spartina alterniflora*.

Phase III will develop a marsh vulnerability index for other vegetation types within the same three test sites. Indicator species will be identified that are typically found in other areas of coastal Delaware. These species can be homogeneous communities (species specific index) or common heterogeneous communities (composite index). Based on the maximum/minimum elevations derived from the Arc/GIS analysis, a site specific indicator species composite tidal growth range will be developed. These site specific values will be compared with the other regions to determine if a Statewide or regional composite Marsh Vulnerability Index can be developed for marshes dominated by certain indicator species. The individual marsh polygon elevations will be compared with the Marsh Vulnerability Index to estimate the sustainability of that particular marsh.

Phase IV will produce a Statewide Marsh Vulnerability Index for several indicator marshes throughout the State. Contiguous areas of indicator marshes along the Delaware Coast will be identified and these areas will be defined as polygons in Arc/GIS. A random sampling of the sites will be done to insure the proper identification of the species. Mean, median, maximum and minimum elevations will be determined for each marsh polygon, and actual marsh elevation will be determined with LiDAR data. Additional field sampling may be conducted to verify elevations. The tidal ranges and mean tide elevation will be determined for a range of regions along the Delaware Bay coast. Based on the maximum/minimum elevations derived from the Arc/GIS analysis, a refined indicator species tidal growth range (both species specific and composite indexes) will be developed. The indicator species in marshes throughout the State will then be classified based on marsh species structure, larger contiguous marshes will then be classified using the Marsh Vulnerability Index. The outcome of Phase IV is contingent upon Phase I and a positive index created for *Spartina alterniflora*.

#### ACTIVITIES/SCHEDULE:

1. *Phase I:* Develop *Spartina alterniflora* index for DNERR and CIB locations.
2. *Phase II:* Develop *Spartina alterniflora* index for coastal Delaware locations.
3. *Phase III:* Develop multiple species indexes for DNERR and CIB locations.
4. *Phase IV:* Develop multiple species indexes for coastal Delaware locations

<b>Activity</b>	<b># months req' for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	12	December 2010	Fieldwork Complete/ Processing In Progress
<b>2</b>	12	December 2011	In Progress
<b>3</b>	12	March 2012	Pending
<b>4</b>	12	March 2013	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS (Coastal Delaware Refuge Complex)

University of Delaware

## PRIME HOOK NWR SALINITY/NUTRIENT/SEDIMENT/WATER LEVEL STUDY

Coastal areas and natural resources are particularly vulnerable to climate change, especially with respect to accelerated sea level rise, shoreline erosion, increased storm frequency and intensity, changes in rainfall, and related flooding among other potential impacts. Investigation of such impacts, specifically salinity changes, nutrient inputs and sediment transport within the coastal impoundments at Prime Hook, will be conducted to determine the consequences of management practices and natural events.

Data collection will involve installing monitoring equipment to measure salinity and water level, and conducting salinity transects within the impoundments. Water quality will also be monitored, specifically total sediment solids (TSS) and nitrogen/phosphorus compounds to aid in determining sediment and nutrient fluxes in and out of the impoundments.

### GEOGRAPHIC LOCATION:

Prime Hook National Wildlife Refuge.

### OUTCOME:

This study will result in installation of real-time monitoring network; written reports that include summary of results; discussion of data analysis and statistical procedures. Results will be used to quantify current conditions in the impoundments and predict future changes of future management techniques.

### ACTIVITIES/SCHEDULE:

4. *Installation of monitoring equipment:* Install 7 water level and salinity recorders and set up real-time network
5. *Perform salinity transects:* Perform a series of salinity transects within impoundments II & III
6. *Collection of nutrient and sediment data:* Purchase of sampling equipment, design sampling protocols and collect data for seasonal baseline and storm conditions.
7. *Analyze data and write reports:* Data collected will be analyzed and interpreted leading to an interim reports. These report will be used as a basis for a more detailed study and support management efforts of the Refuge

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	2	Oct 2010	Completed
<b>2</b>	24	Oct 2012	Ongoing
<b>3</b>	24	Dec 2012	Pending
<b>4</b>	NA	Ongoing	Ongoing

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS

## SEDIMENT ELEVATION TABLES

Sediment elevation tables (SETs) provide a nondestructive method for making highly accurate and precise measurements of sediment elevation in intertidal and subtidal wetlands over long periods of time, relative to a fixed subsurface datum. Data collected using SETs can be used to determine both the influence of a single meteorological event on sediment surface elevation and a long-term trend in elevation change. This information will help increase our understanding of sedimentation rates in different marshes, sea level rise effects in these marshes, and potential management techniques.

This project will continue to collect data from established SETs within the St. Jones and Blackbird Creek estuaries. These SETs have datasets that began in 2004-2005 for Blackbird Creek and 2004 and 2007 for St. Jones River. The datasets contain total surface elevation change, shallow surface elevation change, sedimentation, deep subsidence, and shallow subsidence trends.

Marsh surface elevation changes are not merely being controlled by sediment deposition or erosion; subsurface processes are playing a major role in controlling elevation. Separating the influences of the biological (root growth), geological (soil compaction) and hydrological processes (groundwater storage) can be very difficult at best. Measurements from the deep benchmark will document and illustrate the effect that subsidence and compaction (the consolidation and dewatering of the fine grained material deep in the marsh sediments) are having on marsh surface elevation, with these changes in the zone of deep subsidence. The shallow benchmark will localize the effects that occur in the root zone (from the surface to ~ 30 to 50 cm below the sediment surface), such as enhanced growth due to nutrient fluxes, decomposition, compaction, dewatering, and pore water fluxes. Thus, it can be determined whether the subsurface influences are occurring (in the root zone or at deeper depths) and make a first approximation of which processes are dominating elevation change.

### GEOGRAPHIC LOCATION:

The project will be conducted within the St. Jones Estuary in Kent County, Delaware and the Blackbird Creek Estuary in New Castle County, Delaware.

### OUTCOME:

This study will result in a written report that includes a summary of results, discussion of data analysis and statistical procedures. Results can then be used to determine both the influence of a single meteorological event on sediment surface elevation and a long-term trend (i.e. decades) in elevation change, as well as make predictions for future elevation changes in our local marshes.

### ACTIVITIES/SCHEDULE:

1. *SET Monitoring*: SETs will be monitored and read in the St. Jones and Blackbird watershed every 3 months, approximately at the end of each season (i.e. fall, winter, etc.) on the same lunar cycle. Readings will take a total of 6 days per monitoring cycle (3 days each for the St. Jones and Blackbird), for a total of 24 field days for the year. Winter readings could be skipped due to high ice volumes on the marsh surface, which negate the ability to reliably measure the marsh surface.
2. *Status and Trends Report*: A status and trends report of the SET data will be drafted and peer reviewed every two years, for both the St. Jones and Blackbird SET networks. The first report will be completed by February 2011. The report will also include a gap analysis on the current coverage of SET networks across the state and highlight the gaps in spatial

distribution, and make recommendations for future SET placements that could help increase the wetland monitoring.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	On going	Expected 15 to 20 year data set (2019)	On going
2	2	First report, February 2011	On going

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

DNREC Watershed Assessment

Center for the Inland Bays

## IMPLEMENTATION ACTIONS

### CITY OF NEW CASTLE COASTAL RESILIENCY PROJECT

This project is designed to assist the community of the City of New Castle, Delaware in their efforts to reduce hazard vulnerability that currently exists and that could potentially increase in the future due to the impacts of climate change. The City of New Castle currently experiences a number of coastal related problems including; nuisance flooding of streets and road closures due to flooding; storm damage and erosion of dikes; periodic property flooding; and other coastal hazard impacts.

Before communities can develop effective hazard mitigation strategies, they must first identify their hazard risks and assess their vulnerability to the impacts of those hazards. This project will conduct a community-wide vulnerability assessment with broad community involvement and engagement. This will result in an action plan of prioritized projects designed to make the community more resilient, or at a minimum be prepared to recover, from damages associated with coastal hazards.

#### GEOGRAPHIC LOCATION:

City of New Castle

#### OUTCOME:

The goal of this project is to develop a community-wide action plan that increases the resiliency of the City of New Castle, Delaware to the current and future affects of coastal storms and climate change. The project will develop a proactive plan that outlines the specific vulnerabilities of the community and the best actions to be pursued to address these issues. This will include actions to address current risks as well as future risks associated with climate change, including the potential impacts of sea level rise, increased storm frequencies and intensities, tidegate and dike problems or failures, wetland loss, and other impacts.

#### ACTIVITIES/SCHEDULE:

1. *Data Collection and Synthesis:* DCP has submitted a Request for Qualifications (RFQ) in search of firms that will assist in collecting data on the existing tide gates and dikes. More specifically, the selected firm will:
  - a. Perform dike breach analysis and prepare inundation mapping for selected dikes around the City of New Castle
  - b. Perform tide gate analysis including functionality with anticipated sea level rise.
  - c. Prepare Emergency Action Plans for selected dikes around the City of New Castle.
  - d. Prepare Operation and Maintenance Manuals for dikes and tide gates around the City of New Castle.
  - e. Provide engineering support services to the Department as requested in response to dike-related incidents and emergencies including post-incident tasks such as data collection, review and assessment of structures and facilities, and assisting the Department or City of New Castle with planning, designing, and implementing dike repairs.

In addition, existing information will be analyzed and disseminated to provide a factual context to community members about their current storm flooding risk and vulnerabilities.

2. *Vulnerability Assessment:* Conduct a more detailed vulnerability assessment to be used as a guide for developing mitigation strategies and prioritizing mitigation projects.
3. *Strategy Development:* Utilize the detailed results of the vulnerability assessment to develop a final prioritization of needs and a set of strategies to address these needs.
4. *Action Plan Implementation:* A longer term effort to implement the action plan with short term assistance from DCP.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Data Collection and Synthesis</b>		October 2010	Dike Evaluation and Maintenance Plan preparation in progress
<b>Vulnerability Assessment</b>	-----	Summer 2011	In progress
<b>Strategy Development</b>	-----	Summer 2011	Developing workgroup for implementation planning
<b>Action Plan Implementation</b>	-----	Summer 2011	Not Started

#### AGENCIES INVOLVED:

DNREC Division of Watershed Stewardship

DNREC Division of Fish and Wildlife

Delaware Emergency Management Agency

New Castle County Emergency Management

Federal Emergency Management Agency

Delaware Department of Transportation

UD Sea Grant

City of New Castle

## DEVELOPMENT OF A COASTAL FLOOD MONITORING SYSTEM FOR DELAWARE

In the last two decades, storms such as Hurricanes Katrina and Ike along the Gulf of Mexico and Floyd and Hugo along the Atlantic Coast of the United States have resulted in significant loss of life, injuries and property damages reaching well over 100 billion dollars. Much of the damage associated with these and other tropical and extra-tropical weather systems is associated with severe coastal flooding. The Delaware coastline is extremely vulnerable to such events, examples being the great March 1962 storm and the recent coastal flooding incident of May 12, 2008 which left at least one person dead and many homeless after ocean flood waters destroyed homes, especially along the Delaware Bay Coast of Kent County. The added concern of sea-level rise and its effect on the frequency and intensity of coastal flooding events, further emphasizes the need for a modern, dependable coastal flood monitoring system for Delaware's coastal communities.

This project will develop a real-time coastal flood monitoring and warning system for the coastal communities within Kent County, Delaware. This system will serve as a prototype for similar protection along the entire Delaware coast. We will build on the existing competencies of the Delaware Environmental Observing System (DEOS) and the Delaware Geological Survey (DGS) in the development of this prototype system. The deliverables from this project will directly impact several State agencies including the Delaware Department of Natural Resources and Environmental Control (DNREC), the Delaware Emergency Management Agency (DEMA), the Delaware Department of Transportation (DelDOT) and the Delaware National Estuarine Research Reserve (DNERR). Moreover, the proposed system will have a direct impact upon the safety and well-being of Delaware's coastal communities. The system will allow State constituencies to be informed as to tidal conditions and possible flooding situations up to 120-hours in advance of their occurrence. Moreover, the system will indicate those areas that are most likely to be affected by any tidal flooding (roadways, facilities, homes, etc.) allowing for immediate response by appropriate State and County agencies.

### GEOGRAPHIC LOCATION:

Coastal Kent County Delaware

### OUTCOME:

When complete, DEOS and DGS observation sites will continuously monitor environmental conditions across the Delmarva Peninsula. The DEOS will also ingest forecasted tidal levels, based upon astronomical and meteorological conditions, provided through NOAA. When a forecasted (or real-time) critical tidal level is reached, the DEOS ALERTS system will send a message to all interested State officials warning that a coastal flooding situation is possible, which will prompt them to go to the Coastal Flood Monitoring web page. The web page will contain pertinent real-time and forecasted tidal and meteorological information as well as flood inundation maps for each major coastal community along the Kent County coast. Maps will be produced at appropriate flood levels using the latest LIDAR elevation data. Both paper (for dissemination to State and County agencies) and digital (for inclusion on the Coastal Flood Monitoring web page) maps will be produced.

Development of the system will proceed in tandem with the completion of the coastal monitoring GAP Analysis and the inland flood inundation survey. The GAP Analysis will both inform and be informed by the coastal flood monitoring system development. The survey of high water marks during previous coastal flooding events will be conducted using standard surveying techniques by the Delaware Geological Survey. High water marks will be identified, their history confirmed and

the inundation level recorded. This data will be used in conjunction with observed tide heights at USGS tidal monitoring points to better understand the inland inundation associated with various tidal levels along the coast. The association between tide levels at current coastal monitoring sites and inland flood levels is critical in developing statistical relationships that can be used in the development of a coastal flood model that accurately depicts possible inland flooding given a prediction of tidal anomalies at current monitoring sites.

#### ACTIVITIES/SCHEDULE:

1. *Data Collection & Database Modification:* Perform coastal flood inundation surveys, integration of “forecast” data into DEOS data base structure, initial production of flood inundation maps for coastal communities, modification of DEOS ALERTS system for forecast data.
2. *System Integration, Testing & Implementation:* Completion of flood inundation maps, testing of DEOS ALERTS system with forecasted data, development of Coastal Flood Monitoring web page, development of prototype coastal flood statistical model, implementation of system and final report of the project to be presented to DNREC.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	6	January 2010	Completed
2	9	October 2010	Completed

The website for the Coastal Flood Warning System can be found linked to the DEOS website at: <http://www.deos.udel.edu/index.html>

#### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware, Dept of Geography

Delaware Geological Survey

University of Delaware EPSCOR

## DEVELOPMENT OF A COASTAL RESILIENCY ACTION PLAN FOR BOWERS BEACH

Bowers Beach, Delaware is a small Bayfront community in Kent County located between the St. Jones and the Murderkill River. This small town is home to a small commercial fishing fleet and is a popular place for recreational boaters. Although its location makes it attractive for waterfront living and recreating, its location also makes the Town particularly vulnerable to the effects of coastal storms and sea level rise.

This project is designed to assist the community of Bowers Beach, Delaware in their efforts to reduce coastal hazard vulnerability that currently exists and that could potentially increase in the future due to the impacts of sea level rise. Bowers Beach currently experiences a number of coastal related problems including nuisance flooding of streets, episodic storm damage, coastal erosion, and other coastal hazard impacts.

The goal of this project is to develop a community-wide action plan that increases the resiliency of Bowers Beach, Delaware to the current and future effects of coastal storms and seal level rise. The project will develop a proactive plan that outlines the specific vulnerabilities of the community and the best actions to be pursued to address these issues. This will include actions to address current risks as well as future risks associated with climate change, including the potential impacts of sea level rise, increased storm frequencies and intensities, increased rates of erosion, salt water intrusion, wetland loss, and other impacts.

### GEOGRAPHIC LOCATION:

Town of Bowers Beach, Kent County, Delaware.

### OUTCOME:

The final outcome will be an action plan of prioritized projects designed to make the community more resilient, or at a minimum be prepared to recover, from damages associated with coastal hazards. The Town will also acquire the skills necessary to identify and seek out funding opportunities to finance project implementation.

### ACTIVITIES/SCHEDULE:

1. *Phase I-Data Collection and Synthesis:* This first phase of the project will include the collection, analysis, and dissemination of existing information to provide information to community members about their current storm flooding risk and vulnerabilities.
2. *Phase II-Vulnerability Assessment:* Phase two will include a detailed workshop(s) to gather further information and to conduct a detailed vulnerability assessment to be used as a guide for developing mitigation strategies and prioritizing mitigation projects. A Hazards Characterization workshop was conducted to collect the personal experiences from coastal storm and flooding events from the town residents, as well as to identify their initial concerns relating to these storm events. The information gathered during this workshop will be used by a technical workgroup, comprised of State and County experts in project planning and hazard preparations and town representatives, for development of a formal vulnerability assessment and initial mitigation strategy.

3. *Phase III-Strategy Development:* Phase three will utilize the detailed results of the vulnerability assessment to develop a final prioritization of needs and a set of strategies to address these needs.
4. *Phase IV-Implementation:* This phase will be a longer term effort to implement the action plan. Delaware Coastal Programs will take on an advisory role in assisting the town with procuring funding, project design and tracking.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Phase I</b>	9	Winter 2010	Drainage Study ongoing; project webpage published
<b>Phase II</b>	9	Winter 2010	Hazard Workshop conducted and summary document completed;  Assessment workshop conducted; Assessment workshop evaluation ongoing.
<b>Phase III</b>	9	Winter 2010 Spring 2011	-----
<b>Phase IV</b>	12	Spring 2011	-----

AGENCIES INVOLVED:

Town of Bowers Beach

Division of Watershed Stewardship -Shoreline and Waterway Management Section and Drainage Section

Delaware Emergency Management Agency

Kent County Emergency Management

Federal Emergency Management Agency

Delaware Department of Transportation

UD Sea Grant

## POLICY DEVELOPMENT

### DEVELOPMENT OF A STATEWIDE SEA LEVEL RISE ADAPTATION PLAN

Sea level rise will have economic, social and environmental effects throughout the State of Delaware. Sea level rise increases the height of storm waves, making more areas vulnerable to storm damage and can inundate low lying areas, causing losses to tidal wetlands, habitat, and agricultural areas. Sea level rise also can cause higher water tables and salt water intrusion, interfering with the septic systems, drinking water and irrigation water. These effects have implications for coastal access and recreation, transportation networks, public safety and land use patterns.

To address these issues, the Delaware Coastal Programs will develop a Statewide Adaptation Plan for Sea Level Rise. Using the data and information collected from other parts of the Sea Level Rise Initiative in combination with the expertise of many other agencies, the adaptation plan will recommend policy changes and practices that will ensure that Delaware makes informed policy and investment decisions today to prevent damage and losses to infrastructure, resources and homes tomorrow. Recommendations will be based upon a careful assessment of potential effects to landowners, communities, economies, natural resources and infrastructure using the best available science and technology.

Development of the Sea Level Rise Adaptation Plan will be guided by an Advisory Committee that is comprised of representatives from state agencies, municipal governments, business and development advocacy groups and environmental advocacy groups. Significant opportunities for public involvement will also be integral to the development of the plan.

#### GEOGRAPHIC LOCATION:

This project will be statewide.

#### OUTCOMES:

The final outcome of this project will be the publication of a Statewide Sea Level Rise Adaptation Strategy that will outline recommended policies and management strategies to reduce the State's vulnerability to the impacts of Sea Level Rise.

Additional outcomes will include:

- Proceedings Document: Sea Level Rise Issues Characterization Workshop
- Statewide Assessment of Delaware's Vulnerability to Sea Level Rise
- Proceedings Document: Sea Level Rise Adaptation Strategies Workshop
- Increased awareness of the impacts of Sea Level Rise at the state and local level
- Increased interagency coordination on Sea Level Rise issues
- Public outreach
- Implementation of strategies

#### ACTIVITIES/SCHEDULE:

1. *Initial Issues Characterization Workshop:* One-day workshop to begin discussing and outlining potential impacts of sea level rise in Delaware. This workshop was held in March, 2009.
2. *Formation of Advisory Committee:* Agencies and organizations will be invited to participate in the Sea Level Rise Advisory Committee and monthly meetings will convene.
3. *Vulnerability Assessment:* Advisory Committee and Delaware Coastal Programs staff will conduct a statewide screening assessment of Delaware's potential vulnerability to sea level rise.
4. *Strategy Development:* Recommendations for strategies to reduce Delaware's future vulnerability to sea level rise will be drafted by the Advisory Committee and during a public workshop. These strategies will be refined and made available to the public for comment prior to finalizing the document.
5. *Implementation of Priority Strategies:* Strategies will be ranked by the Advisory Committee. Funding and other resources will be sought to implement priority strategies.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	2	March 2009	Completed
2	2	November 2010	Underway
3	6	February 2011	Underway
4	8	October 2011	Not yet begun
5	**	**	Not yet begun

\*\* Implementation will be an on-going task with no certain end date

#### AGENCIES INVOLVED:

The following agencies and organizations were invited to participate in the Advisory Committee:

Delaware Department of Agriculture

Delaware Department of Health and Social Services

Delaware Department of Natural Resources and Environmental Control

Delaware Department of Transportation

Delaware Department of Safety and Homeland Security

Delaware Economic Development Office

Delaware Farm Bureau  
Delaware Insurance Office  
Delaware League of Women Voters  
Delaware Nature Society  
Delaware Office of Management and Budget  
Delaware Office of the Governor  
Delaware Realtors Association  
Delaware State Chamber of Commerce  
Home Builders Association of Delaware  
The Nature Conservancy, Delaware Chapter  
Positive Growth Alliance  
Tidewater Utilities, Inc.  
University of Delaware College of Earth Ocean and the Environment

## MID-ATLANTIC REGIONAL COUNCIL ON THE OCEANS (MARCO)

In June 2009 the Governors of Delaware, Maryland, New Jersey, New York, and Virginia convened a summit to mark the signing of the *Mid-Atlantic Governors' Agreement on Ocean Conservation* and the establishment of the Mid-Atlantic Regional Council on the Ocean (MARCO). Discussions held at the Governors Summit built on expert knowledge and led to the identification of initial actions that advance each of the Governors' four shared priorities. Under the MARCO umbrella the five states are working together to address the four priority issue areas which include: protection of sensitive and unique offshore habitat areas; support for the sustainable development of offshore renewable energy; prepare the region's coastal communities for the impacts of climate change on ocean and coastal resources; and promote improvements in the region's coastal water quality. MARCO has recently added a fifth priority to address coastal and marine spatial planning (CMSP) in light of the President's Ocean Policy Task Force recommendations to develop a national framework for CMSP. CMSP is seen by MARCO as a means to advance most, if not all, of the four priorities and each state is taking steps to aid in the development, coordination, and integration of coastal and marine spatial plans for the region.

The Governors Agreement also called for MARCO to hold a Stakeholder Workshop on the initial action plan. In December 2009, key state and federal agency representatives along with high-profile leaders of the full range of ocean interests learned from each other, deliberated, and made commitments to advancing MARCO's shared actions on its priority areas. Based on the valuable feedback and dialogue from the stakeholder workshop, MARCO is collaborating with federal partners to implement the priority actions and is drafting an updated action plan. The DCP hosted two two-day MARCO working meetings in May and August 2010 to further the state-federal partnerships and the updated action plan.

More information can be found on the MARCO website: [www.midatlanticocean.org](http://www.midatlanticocean.org).

### GEOGRAPHIC LOCATION:

Mid-Atlantic region, including the states of Delaware, New York, New Jersey, Maryland, and Virginia.

### OUTCOME:

MARCO will result in improved management of Mid-Atlantic coastal and ocean resources. The collaborative effort will improve outcomes by instituting a regional, ecosystem-based approach and will foster a cooperative and constructive relationship among the states. It will also provide leverage for greater federal investment and action on the states' coastal and ocean management priorities.

### ACTIVITIES/SCHEDULE:

1. *Refine action plan and implement recommendations:* The action plan will be refined based upon the results of the December 2009 stakeholder workshop, the Presidents' Ocean Policy Task Force recommendations and National Ocean Policy, and the recent two day workshop with federal representatives held in August 2010. The plan outlines the goals, specific objectives, and initial actions for each of the four priority areas. Each initial action specifies which state will take the lead on it, which objective(s) it advances, and a proposed timeframe or completion date.

2. *Working Meetings:* The DCP will host and/or attend quarterly/triannual MARCO working meetings for both state and federal representatives.
3. *Stakeholder Engagement:* MARCO is in the process of applying for Federal grant funds to help organize and facilitate stakeholder engagement workshop(s).
4. *ELI Policy Review:* The DCP has contracted with the Environmental Law Institute (ELI) to conduct a detailed review and assessment of the laws, policies, and programs related to offshore renewable energy development activities in the Mid-Atlantic states coastal zones and adjacent federal waters. This will focus on Delaware, but also include information from the other five MARCO states. ELI began work in September 2010 and is on schedule to complete by April 2011.
5. *Regional SLR Adaptation:* The DCP is the lead on addressing MARCO's goal of preparing the region for sea level rise impacts on regional infrastructure, coastal habitat, and shoreline management. DCP will guide the development of vulnerability assessments and sea level rise scenarios for the MARCO region and to promote regional information exchange about adaptation across the states.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	12	June 2011	In progress
2	12	October 2011	In progress
3	24	October 2012	Not yet initiated
4	6	March 2011	In progress
5	2	October 2012	In progress

**AGENCIES INVOLVED:**

States of Delaware, New York, New Jersey, Maryland, and Virginia

## SUSTAINABLE COASTAL COMMUNITIES

Most land use decisions in Delaware are made at the local level, yet those making decisions often lack technical expertise and/or planning resources. To address the lack of technical and planning resources, the Delaware Coastal Programs offers grants and technical assistance to local governments, state agencies and not-for-profit organizations for planning, natural resource management and coastal hazard mitigation.

In previous years, this funding and technical assistance has helped communities develop ordinances, incorporate natural resource considerations into comprehensive land use plans, inventory natural resources and restore important coastal habitats. In 2009 and beyond, the grant program will be more focused towards assisting community planning for reducing impacts resulting from coastal hazards and assessing vulnerabilities and risks to plan for future impacts of sea level rise.

### GEOGRAPHIC LOCATION:

Grants will be available Statewide, through a competitive RFP process.

### OUTCOME:

This program will result in improved management of Delaware's coastal resources through incorporation of coastal hazard and natural resource considerations into local comprehensive plans. This includes coastal storm resiliency planning, development of coastal management ordinances to reduce impacts, and educational outreach for Delaware's local governments.

The DCP anticipates funding and assisting with 3 – 5 projects per year.

### ACTIVITIES/SCHEDULE:

1. *Release RFP and Award Grants:* The funding will be announced through a “Request for Proposals.” Grant proposals received will be ranked by a committee of resource experts and successful grant applicants will be notified.
2. *Grants Management:* DCP staff will negotiate contracts for each grant recipient and will provide technical assistance until the project has been completed.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	4	December 2010	Underway
2	14	March 2012	Not yet underway

### AGENCIES INVOLVED:

Delaware Coastal Programs

## COMMUNICATION, TRAINING AND PUBLIC INVOLVEMENT

### COMPREHENSIVE MARKETING & OUTREACH STRATEGY FOR SEA LEVEL RISE

In order to effectively communicate to the public and decision maker audiences regarding sea level rise issues, the Delaware Coastal Programs (DCP) established a Sea Level Rise Outreach Strategy Committee comprised of educators, marketers, and communication specialists from the Delaware National Estuarine Research Reserve, Delaware Sea Grant, the Partnership for the Delaware Estuary, DNREC – Public Affairs, DNREC – Shoreline and Waterway Section, in addition to staff from DCP to develop a comprehensive sea level rise marketing and outreach strategy. The strategy provides a clear, coordinated message with information and materials developed and disseminated by all of the organizations of the Committee including Delaware Coastal Programs, Delaware National Estuarine Research Reserve.

As part of the development of this comprehensive strategy, a statewide survey to gauge public knowledge and opinions on sea level rise and its impacts on Delaware was completed in the spring of 2010. This survey provides information about Delaware residents' awareness and understanding of key issues regarding climate change and sea level rise; determine their perception of its overall effect on the economy and ecology of the state; and explore public opinion regarding long range planning for sea level rise loss and damage prevention. Using the results of this survey, as well as other studies and reports focused on improving communications on sea level rise and climate change, a comprehensive marketing and outreach strategy has been drafted to enhance the public and coastal stakeholders' awareness and response to sea level rise.

The strategy considers a variety of audiences (such as local, county, and state government officials, local and regional planners, economic development representatives, agriculture representatives, university researchers, educators, and property owners) and includes workshops, seminars, brochures, factsheets, public service announcements, media buys, website development and/or outreach displays.

#### GEOGRAPHIC LOCATION:

Statewide

#### OUTCOME:

A comprehensive marketing and outreach strategy and an implementation/work plan have been drafted.

#### ACTIVITIES/SCHEDULE:

1. *Strategy Development:* An inventory of existing Sea Level Rise marketing and outreach programs will be completed and will be analyzed along with results of the Sea Level Rise Attitudes and Perception Survey. This analysis will then be interpreted to design a targeted Marketing and Outreach program.
2. *Strategy Implementation:* Activities listed in the strategy will be implemented.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	4	Fall 2010	Draft Completed
<b>2</b>	Ongoing as needed	-	Underway

#### AGENCIES INVOLVED:

##### DNREC

Delaware Coastal Programs

Division of Watershed Stewardship/Shoreline & Waterway Management

Public Affairs

Delaware Sea Grant

Partnership for the Delaware Estuary

Responsive Management

## SEA LEVEL RISE INTERNET MAP VIEWER

Land-use decisions in Delaware are primarily made at the local level yet, often these smaller towns lack the GIS infrastructure that would allow large scale planning efforts, particularly those related to coastal hazards. Delaware Coastal Programs has made significant investment in GIS data, personnel, and hardware over the years. Transferring the benefits of this investment to community decision makers is vital to the success of these planning efforts.

As part of DCP's efforts assisting local governments with Coastal Hazard and Community Resilience Planning, data will be created and shared with the local decision makers and the community. Internet based mapping applications can be a useful tool to affect this sharing. Most local governments and citizens have access to basic internet browsers either at home or in public libraries. Online mapping tools such as Google Maps and Virtual Earth provide free, lightweight mapping tools that members of the public can use to participate in planning efforts. More robust applications, such as ArcGIS Server and Google Earth, allow for more complex views of Community Resiliency information while keeping costs at a minimum (i.e. free to end user). The choice of tool used will depend on the needs of the user and the ability of the tool to present the data.

DCP has utilized ArcGIS Server to produce and distribute Statewide Sea Level Rise Inundation maps for these planning efforts. KML versions of the data are available, however, the datasets are too large to be conveniently accessed on slower internet connections. ArcGIS Server provides both a freely accessible viewer for the general public and advanced access for GIS users to a map service.

### GEOGRAPHIC LOCATION:

Maps of DNEC's Sea Level Rise Inundation Scenarios are available statewide. Distribution of more localized data will initially focus on individual communities undergoing resiliency planning (i.e. Town of Bowers and City of New Castle).

### OUTCOME:

Website(s) providing citizen access to Community Resilience Planning Maps.

<http://www.dnrec.delaware.gov/Pages/SLRMaps.aspx>

### ACTIVITIES/SCHEDULE:

1. *Software needs assessment and acquisition:* Evaluate capabilities of various software to provide mapping data to public through open GIS browsers. Acquire selected software.
2. *Data List:* Develop and initial list of data to be distributed to community members.
3. *Data Conversion:* Convert selected data and maps for distribution.
4. *Website creation:* Establish a new set of pages within DCP's Sea Level Rise web section for distribution of mapping information.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	1 month		Complete
<b>2</b>	1 month		Complete
<b>3</b>	1 month		Complete
<b>4</b>	1 month		Complete

AGENCIES INVOLVED:

Delaware Coastal Programs

DNREC – Office of Information Technology

## STATEWIDE SURVEY TO GAUGE PUBLIC KNOWLEDGE AND OPINIONS ON SEA LEVEL RISE AND ITS IMPACT IN DELAWARE

In order to effectively plan and target sea level rise outreach and technical assistance, it is important to understand the public perception of sea level rise. However, there is currently no statewide information available regarding the level of knowledge Delawareans possess regarding sea level rise and its future impacts; nor whether Delawareans are motivated to change their behaviors to reduce their risk to impacts associated with sea level rise.

In order to address this need, the Delaware Coastal Programs, in cooperation with The Nature Conservancy and with contractual assistance from Responsive Management Inc. conducted a statewide telephone survey during the fall 2009. The survey was designed to be statistically significant and to assess Delaware residents' awareness and understanding of key issues regarding climate change and sea level rise; to determine their perception of its overall effect on the economy and ecology of the state; and to explore public opinion regarding long range planning for sea level rise loss and damage prevention.

The survey was completed in January 2010 and is available for download online:  
<http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/SLRSurveyReport.pdf>

### GEOGRAPHIC LOCATION:

The telephone survey was conducted statewide.

### OUTCOME:

The survey resulted in a written report that includes a summary of results; discussion of data analysis and statistical procedures, a tabular data report, survey graphs and tables, frequency distributions and cross-tabulations. The report has since been used to help in the development of an outreach and marketing strategy, and to guide the content of other outreach and educational products.

### ACTIVITIES/SCHEDULE:

1. *Develop survey instrument:* In cooperation with other interested agencies and Responsive Management, design and test the survey.
2. *Conduct Telephone Survey:* Responsive Management will conduct the phone survey using random dialing.
3. *Analyze Results:* Responsive Management will analyze the results of the survey with appropriate statistical tests.
4. *Prepare Report:* Responsive Management will prepare a final report that provides an executive summary, methodology, data and appropriate charts and graphs.
5. *Distribute and Explain Report:* Final report will be made available via the web and hard copy. Workshops will be held in cooperation with the Nature Conservancy and Responsive Management to explain the results of the survey.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	2	July 2009	Complete
<b>2</b>	2	November 2009	Complete
<b>3</b>	2	December 2009	Complete
<b>4</b>	1	January 2010	Complete
<b>5</b>	6	March 2010	Complete

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

The Nature Conservancy

Responsive Management

PREPARING FOR SEA LEVEL RISE  
DEVELOPMENT OF A SEA LEVEL RISE INITIATIVE

Sea Level Rise Initiative  
Project Compendium  
October 2010



*Photo by: Delaware Shoreline and Waterway Management Section*

*A Compendium of Delaware Coastal Programs' Projects that Address  
Sea Level Rise*



Delaware Coastal Programs

(302) 739-9283



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## THE SEA LEVEL RISE INITIATIVE

In recognition of the importance of the coast to the Nation's commerce, energy development and natural resource protection, the Coastal Zone Act of 1972 was enacted to assist States manage these conflicting uses of coastal areas. At that time, in addition to directing State Coastal Zone Management Programs to address issues of pollution, development, navigation and energy development, the Coastal Zone Act also directed States to prepare for sea level rise.

In recent years, improved climatic and ocean observation systems have made it possible for scientists to better assess the potential for sea level rise and make predictions for the future. These predictions have shown that coastal areas, particularly in the Mid-Atlantic states, will likely see an increased rate of sea level rise. The U.S. Climate Change Science Program's (CCSP) 2009 document, "Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic" recommends that states should prepare for sea level to rise by at least one meter (39 inches) by 2100; the current rate of sea level rise measured by a tide gauge in Lewes Delaware is 13 inches per 100 years. The CCSP prediction is in close agreement with many other predictions by Federal, State and Global agencies and represents a three-fold increase in the historic rate of sea level rise.

This level of sea level rise will have economic, social and environmental effects throughout the State of Delaware. Sea level rise will inundate low lying areas, causing significant losses to tidal wetlands and wildlife habitat. As the high tide line encroaches landward, some important agricultural areas may no longer be suitable for tillage. Sea level rise also can cause higher water tables and salt water intrusion, interfering with the septic systems, drinking water and irrigation water. Most importantly for many coastal communities, sea level rise can increase the effects of storm surge and waves, allowing flooding to occur in areas that may have never previously been susceptible to flooding from storms. All of these potential effects from sea level rise also have implications for coastal access and recreation, transportation networks, public safety and land use patterns.

To help assess, prepare for and minimize the potential impacts of sea level rise, the Delaware Coastal Programs Section of the Delaware Department of Natural Resources and Environmental Control is leading a multi-year Sea Level Rise Initiative. The goal of the Sea Level Rise Initiative is to reduce Delaware's future vulnerability to the effects of sea level rise. This will be accomplished by:

- Providing scientific and technical support for decision-making
- Implementing on-the-ground project in partnership with stakeholders
- Providing educational and outreach opportunities for stakeholders and the public
- Improving existing policies and management practices and/or developing new policies and management practices where necessary

As part of the goal of providing scientific and technical support for decision-making, Delaware Coastal Programs scientists have partnered with the National Wildlife Refuge System, the University of Delaware, local Estuary Programs and other state agencies to fill gaps in our knowledge about coastal storms, tide levels and marsh sediment accretion. This data and information will be used for policy development; communication of this new information is a component of the outreach strategy.

As part of the goal of implementing on the ground projects, Delaware Coastal Programs staff have partnered with the City of New Castle and the Town of Bowers Beach to help them improve their

preparedness for coastal storms and future sea level rise. Related to this effort, and using high resolution elevation data, a real time flood monitoring system is being developed that will greatly improve flood response in coastal communities.

Public involvement and outreach is a critical component of preparing for sea level rise. All of the tools and data developed during the Sea Level Rise initiative will be communicated to the public through websites, presentations, public events, articles and decision-maker workshops. This is detailed in a comprehensive outreach strategy for sea level rise, developed in partnership with the DNREC Watershed Stewardship Division, the Delaware Estuary Program and Delaware Sea Grant.

These projects, along with others described in this document, have been initiated under the Sea Level Rise Initiative to help to build partnerships and capacity, increase resiliency, increase public knowledge of and support for actions to reduce our vulnerability and make decisions based upon the best available science. The Sea Level Rise Initiative is designed to be iterative and will grow and change as new data, outreach and policy needs are identified.

## PURPOSE OF COMPENDIUM OF SEA LEVEL RISE INITIATIVE PROJECTS

The purpose of the Sea Level Rise Initiative Compendium of Projects is to provide an at-a-glance inventory of the projects and initiatives are being conducted as part of the Delaware Coastal Programs' Sea Level Rise Initiative. It is intended to help increase collaboration between agencies, reduce redundancy and overlap in projects relating to sea level rise and to relay information about new (or soon to be available) data, information and tools.

Projects conducted without the assistance or involvement of the Delaware Coastal Programs are not currently reflected in this document. However, there are many other agencies whose work will be essential to preparing for sea level rise and coastal inundation. The Delaware Coastal Programs may in the future consider expanding the scope of this document to include other agencies' work.

Because the projects listed in this document are likely to evolve over time, it is our intent to update this document on a routine basis so that our partner agencies can be kept up to date on sea level rise activities. The most current version of the document will be posted on the Delaware Coastal Programs' sea level rise website.

## FOR MORE INFORMATION

For more information about projects contained within the Sea Level Rise Initiative Compendium, please contact us at (302) 739-9283 or see our website:

<http://www.swc.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx>

## SCIENTIFIC AND TECHNICAL SUPPORT

### BOMBAY HOOK HYDROLOGY/SEDIMENT MOVEMENT STUDY

Coastal areas and natural resources are particularly vulnerable to climate change, especially with respect to accelerated sea level rise, shoreline erosion, increased storm frequency and intensity, changes in rainfall, and related flooding among other potential impacts. Investigation of such impacts, specifically marsh depletion and increased mudflats at Bombay Hook, will be conducted to determine patterns of sediment flux in or out of the depleted marsh area.

Data collection will involve conducting river transects within the Leipsic River using the Acoustic Doppler Current Profiler (ADCP) and associated software to collect and process tide and current data. Water quality will also be monitored, specifically total sediment solids (TSS) to aid in determining sediment fluxes in or out of the depleted marsh area.

#### GEOGRAPHIC LOCATION:

Bombay Hook National Wildlife Refuge.

#### OUTCOME:

This study will result in a written report that includes a summary of results; discussion of data analysis and statistical procedures. Results will be used to predict future changes in marsh depletion and to help determine marsh management techniques to counteract these impacts affecting the tidal marshes at Bombay Hook.

#### ACTIVITIES/SCHEDULE:

1. *Installation of monitoring equipment:* Install 5 water level recorders and 1 Acoustic Doppler Current Profiler.
2. *Perform cross-section current profiles and collect data:* Perform a series of cross-section current profiles at various locations over varying tidal stages and collect water level and ADCP data.
3. *Analyze data and write report:* Data collected to date will be analyzed and interpreted leading to an interim report. This report can be used as a basis for a more detailed study and support future modeling efforts in the Refuge

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	1	May 2009	Completed
<b>2</b>	NA	Ongoing	Ongoing
<b>3</b>	3	March 2011	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS

## COASTAL IMPOUNDMENT ACCRETION RATE STUDY

As an accelerated rate of relative sea-level rise further stresses impounded marshes, there is a greater need to evaluate the long-term sustainability and utility of impoundments in Delaware. In order to do this, baseline data regarding historic sedimentation rates is needed.

Baseline data sets of long-term sedimentation rates in impounded and natural wetlands can be utilized to evaluate the impounded wetlands' ability to achieve optimal habitat benefit under different management strategies and under different sea level rise scenarios

Long-term sedimentation rates over the past 100 and 50 years can be calculated by collecting radioisotopic cores from wetland areas and analyzing them for  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$ . All core sites and the adjacent wetland will be surveyed to tie all data to the tidal datum (NAVD 88). Correlating long-term wetland sedimentation rates to current wetland elevation will enable a detailed analysis of the potential sedimentation deficits that exist within the impoundments, as compared to the reference wetlands. The elevation and sedimentation gradients between the reference and impounded wetlands can be used to calculate potential future elevation trajectories under different sea-level rise and management scenarios.

### GEOGRAPHIC LOCATION:

Monitoring sites were chosen within impounded and reference (natural marsh) sites throughout the State based upon a wetland area change analysis (using a time-series of available imagery), and basins that have been identified as needing detailed study to aid in their management to optimize the future available habitat. Sites that will be studied include: marshes along the Delaware River near New Castle; Ted Harvey Wildlife Area; St. Augustine Wildlife Area; and Primehook National Wildlife Refuge.

### OUTCOME:

When complete, this study will provide information to coastal managers regarding marsh susceptibility to sea level rise under different marsh management scenarios and under different sea level rise scenarios. A long-term comparison of the wetland elevation and sedimentation conditions between the impounded marsh and the "natural" marsh will enable a detailed analysis and comparison of the potential long-term growth conditions and highlight the potential implications for impoundment management that could affect the sustainability of the interior wetlands. This information will allow marsh managers to understand the potential outcomes of sea level rise and adapt their management techniques.

### ACTIVITIES/SCHEDULE:

1. *Initial Impoundment Core Collection:* Radioisotopic cores will be collected from selected marshes. All core sites and adjacent wetlands will be surveyed. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis is scheduled to be complete by December 2009.
2. *New Castle Impoundment Core Collection:* Radioisotopic cores will be collected from 3 impoundments and 2 reference marshes along the Delaware River adjacent to the City of New Castle. All core sites and adjacent wetlands will be surveyed after collection. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis is expected to be complete by December 2010.

3. *Kent County and Lower New Castle County Impoundment Core Collection:* Radioisotopic cores will be collected from Ted Harvey Wildlife Area, St. Augustine Wildlife Area, and Primehook National Wildlife Refuge. The Ted Harvey and St. Augustine sites were selected to expand the scope of the impoundment investigation to include sites along the entire Bay and River coast. All core sites and adjacent wetlands will be surveyed after collection. Samples will be sent for gamma spectroscopy analysis at the University of Delaware College of Earth, Ocean and Environment. Core analysis by UD is expected to be completed by December 2011.
4. *Gap Analysis of Delaware Coast:* A gap analysis of the Delaware River and Bay Coast Impoundments and reference marshes will be conducted to identify areas where additional cores should be collected and analyzed. The previously analyzed cores will be examined to evaluate the spatial and temporal variability within the study areas and evaluate the need for additional coring sites. A total of 18 cores will be collected to fill in the identified data gaps and areas of high spatial sedimentation rate variability.

<u>Activity</u>	<u># months req'd for completion</u>	<u>Activity Start Date</u>	<u>Estimated DCP Completion Date</u>	<u>Estimated Laboratory Completion</u>	<u>Status</u>
1	5	November 2008	March 2009	April 2010	In Progress
2	8 - 10	April 2009	November 2009	December 2010	In progress
3	6	December 2009	May 2010	December 2011	Pending
4	8	May 2010	January 2011	December 2012	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

UD College of Earth, Ocean and Environment

Primehook National Wildlife Refuge (USFWS)

DNREC Division of Fish and Wildlife

## COASTAL MONITORING GAP ANALYSIS

In the last two decades, storms such as Hurricanes Katrina and Ike along the Gulf of Mexico and Floyd and Hugo along the Atlantic Coast of the United States have resulted in significant loss of life, injuries and property damages reaching well over 100 billion dollars. Much of the damage associated with these and other tropical and extra-tropical weather systems is associated with severe coastal flooding. The Delaware coastline is extremely vulnerable to such events, examples being the great March, 1962 storm and the recent coastal flooding incident of May 12, 2008.

As part of a cooperative effort between the University of Delaware and several Delaware State Agencies to better monitor conditions along the Delaware coastline and to provide advance warning of impending coastal flooding events, we propose the completion of a GAP Analysis of pertinent coastal data needs and a comprehensive survey of inland inundation levels during previous coastal flooding events. The GAP Analysis will define the present state of coastal data collection efforts across the state, an “optimum” data collection network and the gap between them, indicating those data that need to be added to the current network. A survey of high water marks from previous coastal flooding events will be used to create a “baseline” data set to aid in understanding the relationships between water levels at tidal monitoring points and inland locations. In this research, an exhaustive inventory of real-time and archived coastal data will be conducted. This inventory will include meteorological, tidal, buoy, water quality and inundation data sources, along with ancillary sources of coastal information (i.e. research publications, modeling work, etc.).

### GEOGRAPHIC LOCATION:

Coastal Delaware.

### OUTCOME:

The final outcome/product will be a report that makes recommendations as to the type of data needed to reach an “optimum” coastal monitoring network, and the spatial placement and temporal resolution of additional sensors that may need to be deployed to reach the optimum configuration. The report is available at:

[http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Gap\\_Analysis\\_Final\\_Report\\_032910.pdf](http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/Gap_Analysis_Final_Report_032910.pdf) or <http://www.deos.udel.edu/delawaregap/index.html>

### ACTIVITIES/SCHEDULE:

1. *GAP Analysis Report:* University of Delaware will conduct the analysis and develop a report that makes recommendations as to the type of data needed to reach an “optimum” coastal monitoring network.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	9	March 2010	Completed

### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware

## COASTAL STORM HISTORY

Several coastal communities in Delaware currently experience storm damage, coastal erosion, and other coastal hazard impacts. In efforts to reduce hazard vulnerability that currently exists and that could potentially increase in the future due to climate change impacts, the Delaware Coastal Programs, along with the University of Delaware are compiling data on historical storms, nor'easters, subtropical storms or hurricanes that may have impacted Delaware's coasts in the past.

This data was previously compiled by the University of Delaware for years up through 1974 and a written report is available. This project will focus on updating the storm data from 1974 to 2009.

### GEOGRAPHIC LOCATION:

Coast of Delaware.

### OUTCOME:

Compendium of historical storm data categorized according to the type of storm, physical characteristics and impacts on coastal communities and natural resources. This can perhaps be used to derive specific scenarios to be modeled for the purpose of future adaptation and preparedness. It will also help to identify where outside expertise should be brought in to provide additional technical assistance for resiliency assessment, planning and implementing. Depending on the detail of the data collected, there may be some insight for prediction of the next potential storm, nor'easter or hurricane and the impacts of such events.

### ACTIVITIES/SCHEDULE:

1. *Storm data collection:* Through analysis of historic data sets and communication with local and state officials and the public, historic storm information will be compiled.
2. *Development of Report:* A compilation report will be developed and distributed. The report will include storm data from 1974 to present including all pertinent data.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Contract signed</b>	n/a	Feb 2010	Completed
<b>1</b>	12	Sept 2010	Completed
<b>2</b>	6	March 2011	Pending

### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware

## DEVELOPMENT OF COASTAL INUNDATION MAPS

Sea Level Rise inundation maps are necessary to determine areas and extent of coastal vulnerability to sea level rise, and will be a key component guiding the development of a Statewide Sea Level Rise Adaptation Plan. While it is relatively straight forward to overlay elevated sea level changes onto existing digital elevation models (DEMs), certain factors must be considered. Primarily, mean tide levels vary along the Delaware Bay Coast and any maps developed must take this into consideration. Secondly, solely using sea level rise will not give a true perspective of inundation, since the major concern will be the flooding from coastal storm surges.

To develop these maps (GIS Layers) a statistical evaluation from the existing 2 long-term NOAA tide level datasets of Lewes (Breakwater Harbor) and Delaware City (Reedy Point) will be performed to establish storm surge elevations above Mean Higher High Water (MHHW) for selected return periods (i.e. 10, 25 50, 100-year return periods). Once these are calculated, the current MHHW levels along the length of the coast will be determined using the NOAA VDatum software. These two datasets will be combined to establish the appropriate elevations to use for coastal inundation. After the Delaware Bay coast is completed, a similar effort will be performed for the Inland Bays and Atlantic Coast.

### GEOGRAPHIC LOCATION:

Coastal Delaware

### OUTCOME:

The final outcome/product will be a series of maps in GIS format that will be based on the bare earth LIDAR data. Several scenarios will be developed using on current sea level rise, predicted average sea level rise and predicted maximum sea level rise for the years 2050 and 2100. Estimates of storm surge added to the predicted elevations will also be provided. These surges will be based on historic data and statistical analysis.

### ACTIVITIES/SCHEDULE:

1. *Statistical Analysis of existing tide data:* Based on existing data for Lewes and Delaware City, develop expected storm surge levels for certain return periods.
2. *Determine MHHW for Bay Coast:* Using VDatum, determine MHHW along Delaware Bay coastline corrected to NAVD88
3. *Develop Inundation Maps for Delaware Bay Coast:* Combining the two developed datasets, produce GIS maps for different seal level and storm surge scenarios
4. *Inland Bays and Atlantic Coast Maps:* Repeat 1-3 for Inland Bays and Atlantic Coast.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	2	September, 2009	Completed
2	<1	October, 2009	Completed
3	2	December, 2009	Completed
4	1	January, 2010	Completed

**It is anticipated that all inundation maps will be frequently updated as new information on sea level rise becomes available.**

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

## DIGITAL COAST

The Digital Coast is a nationwide initiative that is designed to ensure the wise use and management of coastal resources by providing coastal managers with data, training, tools and examples to assist them with emerging and priority coastal issues. The partner network identifies Digital Coast priorities and then works together to address coastal issues.

Currently, the Digital Coast partnership is focused on providing data, tools and examples to coastal managers regarding coastal inundation and sea level rise. Projects to address other coastal issues (i.e., marine spatial planning, conservation) will be developed in the future.

One of the goals behind the creation of the Digital Coast was to unify groups that might not otherwise work together and build a strong collaboration of coastal professionals intent on addressing coastal conservation needs. The Digital Coast Partnership Group is currently comprised of representatives from the Association of State Floodplain Managers, the Coastal States Organization, the National Association of Counties, the National States Geographic Information Council, The Nature Conservancy, and the NOAA Coastal Services Center. Delaware Coastal Programs staff has actively served as part of the Coastal States Organization representatives on this project. The National Oceanic and Atmospheric Administration's

(NOAA) Coastal Services Center is the lead organization for Digital Coast efforts.

### OUTCOME:

In the fall of 2009, the Coastal Inundation Toolkit, was released. The toolkit was being developed by the Digital Coast Partnership Group to help communities understand and address coastal inundation issues. Website components include:

- Understand – Learn about inundation basics and common hazard concepts
- Identify – Download the county-specific charts and graphs that tell your story
- Map – Use the steps provided to discover and map areas of potential impact
- Assess – Use inundation maps to assess community risk, vulnerability, and resilience
- Inform – Use risk communication strategies to illicit change
- Discover – See how other communities are addressing this issue

This tool is expected to be of enormous value as a resource tool for the many groups concerned with and working to address coastal flooding and Sea Level Rise issues in Delaware.

Current and future Modules of Digital Coast resources are available at:

<http://www.csc.noaa.gov/digitalcoast/>

## HYDROLOGIC MONITORING OF THE KITTS HUMMOCK AREA

To properly understand the relationships between the Delaware Bay, interior marsh water levels, ponds, impoundments and the drainage ditch network around Kitts Hummock, a comprehensive water level monitoring program will be established. Establishing a water level monitoring network at key locations will aid in the understating the interrelationships between the water bodies and the influence of the drainage network in the community on these water bodies. This baseline monitoring is one of the prerequisite needs for conducting any defensible modeling and evaluation of the effectiveness of any proposed drainage improvements to the Kitts Hummock area. Additional needs prior to modeling include validation of marsh elevations, detailed documentation and assessment of previous storms, and engineering designs of proposed alterations

This baseline network will use a total of 8 Inset HOBO water level recorders in conjunction with the USGS Tide gauge located approximately 5 kilometers south at Bowers Beach and other currently monitored parameters. Two water level recorders will be placed on the north and south sides of Kitts Hummock Road in the primary N/S drainage ditch approximately 250 meters inland from the Delaware Bay. An additional three water level recorders will be used to examine the effects of marsh water elevation and the northern impoundment of the Logan Lane Tract of the Ted Harvey Conservation Area on the open water area of a private property and the South Bay Drive drainage ditch. The final two water level recorders will be installed in open water areas of the marsh northeast of the community of Kitts Hummock to estimate the tidal backwater effects north of Kitts Hummock Road. A final recorder will be housed at the Delaware National Estuarine Research Reserve (DNERR) to measure barometric pressure changes which will be used to atmospherically correct the readings of the water level recorders. The recorders will be surveyed to an accuracy of  $\pm 2$  cm vertical, and maintained and downloaded monthly by staff from the DNERR.

### GEOGRAPHIC LOCATION:

This project encompasses the area surrounding Kitts Hummock, Kent County, DE, including the private marsh lands north and south of the community and the DNREC/DFW Logan Lane Tract of the Ted Harvey Conservation Area.

### OUTCOME:

Once sufficient data has been collected, which includes a minimum of 3 months of data and at least 3 significant storm events, the data will be compiled. Data on rainfall and wave height, period and direction, currently being monitored by the DNERR, will be incorporated into the data set and then the dataset will be analyzed. This analysis will include examining the Bay tide effects on marsh water/drainage ditch elevations; relationships of surrounding water levels on the Thompson open water area; probable pathways of tide related flooding; and a qualitative evaluation of the expected effectiveness of drainage ditches in the area during different tidal cycles/storm events.

### ACTIVITIES/SCHEDULE:

1. *Data Collection:* Install data recorders, survey locations and collect data.
2. *Data Analysis:* Analyze data, run computer simulations, develop qualitative evaluation of storm event drainage scenarios.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	3-5	October 2009	Complete
<b>2</b>	3	December 2009	Complete

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

DNREC Drainage and Stormwater Section

DNREC District Operations

## MARSH LOSS ANALYSIS (INTERIOR OPEN WATER CREATION)

Staff from Bombay Hook NWR contacted the Delaware Coastal Programs for assistance with their 5-year Biologic Review of the refuge. Refuge staff felt that DCP's experience with GIS analysis could help them answer some questions they had about the changing habitat of the refuge. Coastal change, rising sea levels, erosion and land subsidence are increasingly tough issues facing coastal managers, engineers, and planners charged with developing and protecting coastal habitats and communities in vulnerable coastal zones. Understanding these threats depends on early detection, and solutions will require vigorous public debate over engineering solutions vs. strategic retreat. The drastic changes at Bombay Hook National Wildlife Refuge (NWR) may be a harbinger of coast-wide habitat changes in the future.

The coastal areas of Bombay Hook NWR have historically been subjected to significant erosion. Historical shorelines from as far back as 1842 paint a much different picture than exists today. Shores that face the East and Southeast take the worst damage. These areas have the longest fetch allowing the winds to add more power to the waves that break on these shores. For the period 1937-2002, roughly 1700 ft. of erosion occurred along the southern shoreline of Bombay Hook (26 ft/yr). This habitat loss is now coupled with increasing amounts of open water creation in the interior marsh.

Aerial photos from 1979, 1992, and 2002 were examined for expansion of open water areas in the interior marsh. Photos were viewed on a geographic information system and areas of open water were outlined. Results showed that, over the years, open water areas were growing larger and combining together. What had been a mosaic of small areas of open water mixed in vegetated marsh are becoming large tracts of open water with vegetation around the edges. This Study revealed that since 1979, the Refuge has lost a total of 12% of its wetland area; 10% attributed to the creation of interior, open water areas.

No single, direct cause for the wetland loss has yet been identified. Some potential causes including sea level rise, marsh/land subsidence, and snow goose grazing are being looked into. These effects are inter-related and tend to work together to make matters worse. Currently DCP and others are using sediment elevation tables to explore subsidence and sedimentation in regional marshes. It is hoped that if a cause(s) can be determined, adjustments in marsh management can be made to stem the loss of interior area.

This project will investigate the expansion of open water areas in four additional areas throughout the state: the Thousand Acre Marsh region; Blackbird Creek; Milford Neck and Primehook National Wildlife Refuge. For each area, open water areas will be digitized using ArcGIS from historic aerial photographs to determine extent of open water areas over time.

### GEOGRAPHIC LOCATION:

DCP is now expanding the study to other similar marsh areas around the State: 1000 Acre Marsh, Blackbird Creek, Milford Neck Wildlife Area and surrounding private conservation lands; and Prime Hook NWR with nearby areas in Broadkill Beach.

#### OUTCOME:

This project will result in GIS maps of marsh loss over time for the study areas.

It is also hoped that this information can be combined with results from other studies and may shed light on the causes of the wetland loss. This combination of information is expected to lead to management changes that can limit further loss and possibly aid recovery of the marshes.

#### ACTIVITIES/SCHEDULE:

1. *Digitize open water areas:* Bombay Hook.
2. *Digitize open water areas:* 1000 Acre Marsh.
3. *Digitize open water areas:* Blackbird Creek.
4. *Digitize open water areas:* Milford Neck.
5. *Digitize open water areas:* Prime Hook.

Activity	# months req'd for completion	Estimated Completion Date	Status
1.			Complete
2.			Complete
3.			Complete
4.			Complete
5.			Complete

#### AGENCIES INVOLVED:

Delaware Coastal Programs

## MARSH VULNERABILITY INDEX

An index is needed to allow assessment of the long-term viability of Delaware's marshes under differing sea level rise scenarios and to target areas for conservation, restoration and monitoring. The Tidal Marsh Vulnerability Index will be based upon the positive correlation between mean tidal range and elevational growth range of tidal wetland plant species. Biomass sampling, taken from the Mid-Atlantic Wetland Rapid Assessment Method (MidTRAM), will also be incorporated into the Marsh Vulnerability Index to assess marsh health. Once developed, the Sea Level Rise Index for Tidal Marshes tool could be transferred to other states and used for regional comparisons and regional planning.

The Tidal Marsh Vulnerability Index will classify marshes as healthy, degrading or severely degrading. These classifications will be utilized to select areas to conduct detailed sediment accretion rate and other monitoring. Degraded and severely threatened marshes are known to have lower elevations, relative to the tidal prism, and are more prone to catastrophic losses due to sea-level rise and storm events. Understanding the current and historic sedimentation accretion rates of these marshes can help to better predict the longevity and the sediment deficits of these areas and possible management practices that might be implemented to prevent marsh elevation losses (i.e. thin layer application of sediment, vegetation plantings, etc.).

The Tidal Marsh Vulnerability Index, in conjugation with time-series analysis of aerial imagery, will be essential for evaluating wetland vulnerability on a watershed or statewide basis, while enabling the strategic placement of monitoring resources to enhance our efforts to understand the future evolution potential of Delaware's tidal wetlands. All field based monitoring and sampling efforts can be initiated and implemented to evaluate the most severely threatened marsh areas first; the monitoring can then be expanded to encompass other marsh regions as resources become available. Marsh Vulnerability Index classification optimizes the monitoring efforts and resources to the highest levels possible, so the broadest extent of Delaware's tidal wetlands may be evaluate and managed.

### GEOGRAPHIC LOCATION:

Phase I & III will occur in the two components of the Delaware National Estuarine Research Reserve, and the National Estuary Program, Center for the Inland Bays. Phase II & IV will occur in tidal marshes along the Delaware Bay Coast and inland bays.

### OUTCOME:

Phase I will develop a marsh vulnerability index for *Spartina alterniflora* at three test sites located within the Delaware National Estuarine Research Reserve and the National Estuary Program's Center for the Inland Bays. These three target sites encompass all three counties and three different salinity regimes. This phase will use GIS data, aerial photos, LiDAR data and the Statewide Wetland Mapping Program data along with field validation to develop a *Spartina alterniflora* tidal growth range. These site specific values will be compared with the other regions and values the literature to determine if a Statewide or regional Marsh Vulnerability Index can be developed for

*Spartina alterniflora* marshes. Individual marsh polygon elevations will then be compared with the Marsh Vulnerability Index to estimate the sustainability of that particular marsh.

Phase II will develop a statewide Marsh Vulnerability Index for *Spartina alterniflora* marshes. Contiguous areas of *Spartina alterniflora* will be identified using SWMP data and ArcGIS polygons will be created. Marsh elevation and tidal ranges and mean tide elevations will be determined from the LiDAR dataset and/or additional on the ground sampling. Based on the maximum/minimum elevations derived from the Arc/GIS analysis a refined *Spartina alterniflora* tidal growth range will be developed. The *Spartina alterniflora* marshes throughout the State will then be classified using the Marsh Vulnerability Index. The outcome of Phase II is contingent upon Phase I and a positive index created for *Spartina alterniflora*.

Phase III will develop a marsh vulnerability index for other vegetation types within the same three test sites. Indicator species will be identified that are typically found in other areas of coastal Delaware. These species can be homogeneous communities (species specific index) or common heterogeneous communities (composite index). Based on the maximum/minimum elevations derived from the Arc/GIS analysis, a site specific indicator species composite tidal growth range will be developed. These site specific values will be compared with the other regions to determine if a Statewide or regional composite Marsh Vulnerability Index can be developed for marshes dominated by certain indicator species. The individual marsh polygon elevations will be compared with the Marsh Vulnerability Index to estimate the sustainability of that particular marsh.

Phase IV will produce a Statewide Marsh Vulnerability Index for several indicator marshes throughout the State. Contiguous areas of indicator marshes along the Delaware Coast will be identified and these areas will be defined as polygons in Arc/GIS. A random sampling of the sites will be done to insure the proper identification of the species. Mean, median, maximum and minimum elevations will be determined for each marsh polygon, and actual marsh elevation will be determined with LiDAR data. Additional field sampling may be conducted to verify elevations. The tidal ranges and mean tide elevation will be determined for a range of regions along the Delaware Bay coast. Based on the maximum/minimum elevations derived from the Arc/GIS analysis, a refined indicator species tidal growth range (both species specific and composite indexes) will be developed. The indicator species in marshes throughout the State will then be classified based on marsh species structure, larger contiguous marshes will then be classified using the Marsh Vulnerability Index. The outcome of Phase IV is contingent upon Phase I and a positive index created for *Spartina alterniflora*.

#### ACTIVITIES/SCHEDULE:

1. *Phase I:* Develop *Spartina alterniflora* index for DNERR and CIB locations.
2. *Phase II:* Develop *Spartina alterniflora* index for coastal Delaware locations.
3. *Phase III:* Develop multiple species indexes for DNERR and CIB locations.
4. *Phase IV:* Develop multiple species indexes for coastal Delaware locations

<b>Activity</b>	<b># months req' for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	12	December 2010	Fieldwork Complete/ Processing In Progress
<b>2</b>	12	December 2011	In Progress
<b>3</b>	12	March 2012	Pending
<b>4</b>	12	March 2013	Pending

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

USFWS (Coastal Delaware Refuge Complex)

University of Delaware

## PRIME HOOK NWR SALINITY/NUTRIENT/SEDIMENT/WATER LEVEL STUDY

Coastal areas and natural resources are particularly vulnerable to climate change, especially with respect to accelerated sea level rise, shoreline erosion, increased storm frequency and intensity, changes in rainfall, and related flooding among other potential impacts. Investigation of such impacts, specifically salinity changes, nutrient inputs and sediment transport within the coastal impoundments at Prime Hook, will be conducted to determine the consequences of management practices and natural events.

Data collection will involve installing monitoring equipment to measure salinity and water level, and conducting salinity transects within the impoundments. Water quality will also be monitored, specifically total sediment solids (TSS) and nitrogen/phosphorus compounds to aid in determining sediment and nutrient fluxes in and out of the impoundments.

### GEOGRAPHIC LOCATION:

Prime Hook National Wildlife Refuge.

### OUTCOME:

This study will result in installation of real-time monitoring network; written reports that include summary of results; discussion of data analysis and statistical procedures. Results will be used to quantify current conditions in the impoundments and predict future changes of future management techniques.

### ACTIVITIES/SCHEDULE:

4. *Installation of monitoring equipment:* Install 7 water level and salinity recorders and set up real-time network
5. *Perform salinity transects:* Perform a series of salinity transects within impoundments II & III
6. *Collection of nutrient and sediment data:* Purchase of sampling equipment, design sampling protocols and collect data for seasonal baseline and storm conditions.
7. *Analyze data and write reports:* Data collected will be analyzed and interpreted leading to an interim reports. These report will be used as a basis for a more detailed study and support management efforts of the Refuge

Activity	# months req'd for completion	Estimated Completion Date	Status
1	2	Oct 2010	Completed
2	24	Oct 2012	Ongoing
3	24	Dec 2012	Pending
4	NA	Ongoing	Ongoing

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

USFWS

## SEDIMENT ELEVATION TABLES

Sediment elevation tables (SETs) provide a nondestructive method for making highly accurate and precise measurements of sediment elevation in intertidal and subtidal wetlands over long periods of time, relative to a fixed subsurface datum. Data collected using SETs can be used to determine both the influence of a single meteorological event on sediment surface elevation and a long-term trend in elevation change. This information will help increase our understanding of sedimentation rates in different marshes, sea level rise effects in these marshes, and potential management techniques.

This project will continue to collect data from established SETs within the St. Jones and Blackbird Creek estuaries. These SETs have datasets that began in 2004-2005 for Blackbird Creek and 2004 and 2007 for St. Jones River. The datasets contain total surface elevation change, shallow surface elevation change, sedimentation, deep subsidence, and shallow subsidence trends.

Marsh surface elevation changes are not merely being controlled by sediment deposition or erosion; subsurface processes are playing a major role in controlling elevation. Separating the influences of the biological (root growth), geological (soil compaction) and hydrological processes (groundwater storage) can be very difficult at best. Measurements from the deep benchmark will document and illustrate the effect that subsidence and compaction (the consolidation and dewatering of the fine grained material deep in the marsh sediments) are having on marsh surface elevation, with these changes in the zone of deep subsidence. The shallow benchmark will localize the effects that occur in the root zone (from the surface to ~ 30 to 50 cm below the sediment surface), such as enhanced growth due to nutrient fluxes, decomposition, compaction, dewatering, and pore water fluxes. Thus, it can be determined whether the subsurface influences are occurring (in the root zone or at deeper depths) and make a first approximation of which processes are dominating elevation change.

### GEOGRAPHIC LOCATION:

The project will be conducted within the St. Jones Estuary in Kent County, Delaware and the Blackbird Creek Estuary in New Castle County, Delaware.

### OUTCOME:

This study will result in a written report that includes a summary of results, discussion of data analysis and statistical procedures. Results can then be used to determine both the influence of a single meteorological event on sediment surface elevation and a long-term trend (i.e. decades) in elevation change, as well as make predictions for future elevation changes in our local marshes.

### ACTIVITIES/SCHEDULE:

1. *SET Monitoring:* SETs will be monitored and read in the St. Jones and Blackbird watershed every 3 months, approximately at the end of each season (i.e. fall, winter, etc.) on the same lunar cycle. Readings will take a total of 6 days per monitoring cycle (3 days each for the St. Jones and Blackbird), for a total of 24 field days for the year. Winter readings could be skipped due to high ice volumes on the marsh surface, which negate the ability to reliably measure the marsh surface.
2. *Status and Trends Report:* A status and trends report of the SET data will be drafted and peer reviewed every two years, for both the St. Jones and Blackbird SET networks. The first report will be completed by February 2011. The report will also include a gap analysis on the current coverage of SET networks across the state and highlight the gaps in spatial

distribution, and make recommendations for future SET placements that could help increase the wetland monitoring.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	On going	Expected 15 to 20 year data set (2019)	On going
2	2	First report, February 2011	On going

AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

DNREC Watershed Assessment

Center for the Inland Bays

## IMPLEMENTATION ACTIONS

### CITY OF NEW CASTLE COASTAL RESILIENCY PROJECT

This project is designed to assist the community of the City of New Castle, Delaware in their efforts to reduce hazard vulnerability that currently exists and that could potentially increase in the future due to the impacts of climate change. The City of New Castle currently experiences a number of coastal related problems including; nuisance flooding of streets and road closures due to flooding; storm damage and erosion of dikes; periodic property flooding; and other coastal hazard impacts.

Before communities can develop effective hazard mitigation strategies, they must first identify their hazard risks and assess their vulnerability to the impacts of those hazards. This project will conduct a community-wide vulnerability assessment with broad community involvement and engagement. This will result in an action plan of prioritized projects designed to make the community more resilient, or at a minimum be prepared to recover, from damages associated with coastal hazards.

#### GEOGRAPHIC LOCATION:

City of New Castle

#### OUTCOME:

The goal of this project is to develop a community-wide action plan that increases the resiliency of the City of New Castle, Delaware to the current and future affects of coastal storms and climate change. The project will develop a proactive plan that outlines the specific vulnerabilities of the community and the best actions to be pursued to address these issues. This will include actions to address current risks as well as future risks associated with climate change, including the potential impacts of sea level rise, increased storm frequencies and intensities, tidegate and dike problems or failures, wetland loss, and other impacts.

#### ACTIVITIES/SCHEDULE:

1. *Data Collection and Synthesis:* DCP has submitted a Request for Qualifications (RFQ) in search of firms that will assist in collecting data on the existing tide gates and dikes. More specifically, the selected firm will:
  - a. Perform dike breach analysis and prepare inundation mapping for selected dikes around the City of New Castle
  - b. Perform tide gate analysis including functionality with anticipated sea level rise.
  - c. Prepare Emergency Action Plans for selected dikes around the City of New Castle.
  - d. Prepare Operation and Maintenance Manuals for dikes and tide gates around the City of New Castle.
  - e. Provide engineering support services to the Department as requested in response to dike-related incidents and emergencies including post-incident tasks such as data collection, review and assessment of structures and facilities, and assisting the Department or City of New Castle with planning, designing, and implementing dike repairs.

In addition, existing information will be analyzed and disseminated to provide a factual context to community members about their current storm flooding risk and vulnerabilities.

2. *Vulnerability Assessment:* Conduct a more detailed vulnerability assessment to be used as a guide for developing mitigation strategies and prioritizing mitigation projects.
3. *Strategy Development:* Utilize the detailed results of the vulnerability assessment to develop a final prioritization of needs and a set of strategies to address these needs.
4. *Action Plan Implementation:* A longer term effort to implement the action plan with short term assistance from DCP.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Data Collection and Synthesis</b>		October 2010	Dike Evaluation and Maintenance Plan preparation in progress
<b>Vulnerability Assessment</b>	-----	Summer 2011	In progress
<b>Strategy Development</b>	-----	Summer 2011	Developing workgroup for implementation planning
<b>Action Plan Implementation</b>	-----	Summer 2011	Not Started

#### AGENCIES INVOLVED:

DNREC Division of Watershed Stewardship

DNREC Division of Fish and Wildlife

Delaware Emergency Management Agency

New Castle County Emergency Management

Federal Emergency Management Agency

Delaware Department of Transportation

UD Sea Grant

City of New Castle

## DEVELOPMENT OF A COASTAL FLOOD MONITORING SYSTEM FOR DELAWARE

In the last two decades, storms such as Hurricanes Katrina and Ike along the Gulf of Mexico and Floyd and Hugo along the Atlantic Coast of the United States have resulted in significant loss of life, injuries and property damages reaching well over 100 billion dollars. Much of the damage associated with these and other tropical and extra-tropical weather systems is associated with severe coastal flooding. The Delaware coastline is extremely vulnerable to such events, examples being the great March 1962 storm and the recent coastal flooding incident of May 12, 2008 which left at least one person dead and many homeless after ocean flood waters destroyed homes, especially along the Delaware Bay Coast of Kent County. The added concern of sea-level rise and its effect on the frequency and intensity of coastal flooding events, further emphasizes the need for a modern, dependable coastal flood monitoring system for Delaware's coastal communities.

This project will develop a real-time coastal flood monitoring and warning system for the coastal communities within Kent County, Delaware. This system will serve as a prototype for similar protection along the entire Delaware coast. We will build on the existing competencies of the Delaware Environmental Observing System (DEOS) and the Delaware Geological Survey (DGS) in the development of this prototype system. The deliverables from this project will directly impact several State agencies including the Delaware Department of Natural Resources and Environmental Control (DNREC), the Delaware Emergency Management Agency (DEMA), the Delaware Department of Transportation (DelDOT) and the Delaware National Estuarine Research Reserve (DNERR). Moreover, the proposed system will have a direct impact upon the safety and well-being of Delaware's coastal communities. The system will allow State constituencies to be informed as to tidal conditions and possible flooding situations up to 120-hours in advance of their occurrence. Moreover, the system will indicate those areas that are most likely to be affected by any tidal flooding (roadways, facilities, homes, etc.) allowing for immediate response by appropriate State and County agencies.

### GEOGRAPHIC LOCATION:

Coastal Kent County Delaware

### OUTCOME:

When complete, DEOS and DGS observation sites will continuously monitor environmental conditions across the Delmarva Peninsula. The DEOS will also ingest forecasted tidal levels, based upon astronomical and meteorological conditions, provided through NOAA. When a forecasted (or real-time) critical tidal level is reached, the DEOS ALERTS system will send a message to all interested State officials warning that a coastal flooding situation is possible, which will prompt them to go to the Coastal Flood Monitoring web page. The web page will contain pertinent real-time and forecasted tidal and meteorological information as well as flood inundation maps for each major coastal community along the Kent County coast. Maps will be produced at appropriate flood levels using the latest LIDAR elevation data. Both paper (for dissemination to State and County agencies) and digital (for inclusion on the Coastal Flood Monitoring web page) maps will be produced.

Development of the system will proceed in tandem with the completion of the coastal monitoring GAP Analysis and the inland flood inundation survey. The GAP Analysis will both inform and be informed by the coastal flood monitoring system development. The survey of high water marks during previous coastal flooding events will be conducted using standard surveying techniques by the Delaware Geological Survey. High water marks will be identified, their history confirmed and

the inundation level recorded. This data will be used in conjunction with observed tide heights at USGS tidal monitoring points to better understand the inland inundation associated with various tidal levels along the coast. The association between tide levels at current coastal monitoring sites and inland flood levels is critical in developing statistical relationships that can be used in the development of a coastal flood model that accurately depicts possible inland flooding given a prediction of tidal anomalies at current monitoring sites.

#### ACTIVITIES/SCHEDULE:

1. *Data Collection & Database Modification:* Perform coastal flood inundation surveys, integration of “forecast” data into DEOS data base structure, initial production of flood inundation maps for coastal communities, modification of DEOS ALERTS system for forecast data.
2. *System Integration, Testing & Implementation:* Completion of flood inundation maps, testing of DEOS ALERTS system with forecasted data, development of Coastal Flood Monitoring web page, development of prototype coastal flood statistical model, implementation of system and final report of the project to be presented to DNREC.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	6	January 2010	Completed
2	9	October 2010	Completed

The website for the Coastal Flood Warning System can be found linked to the DEOS website at: <http://www.deos.udel.edu/index.html>

#### AGENCIES INVOLVED:

DNREC Delaware Coastal Programs

University of Delaware, Dept of Geography

Delaware Geological Survey

University of Delaware EPSCOR

## DEVELOPMENT OF A COASTAL RESILIENCY ACTION PLAN FOR BOWERS BEACH

Bowers Beach, Delaware is a small Bayfront community in Kent County located between the St. Jones and the Murderkill River. This small town is home to a small commercial fishing fleet and is a popular place for recreational boaters. Although its location makes it attractive for waterfront living and recreating, its location also makes the Town particularly vulnerable to the effects of coastal storms and sea level rise.

This project is designed to assist the community of Bowers Beach, Delaware in their efforts to reduce coastal hazard vulnerability that currently exists and that could potentially increase in the future due to the impacts of sea level rise. Bowers Beach currently experiences a number of coastal related problems including nuisance flooding of streets, episodic storm damage, coastal erosion, and other coastal hazard impacts.

The goal of this project is to develop a community-wide action plan that increases the resiliency of Bowers Beach, Delaware to the current and future effects of coastal storms and seal level rise. The project will develop a proactive plan that outlines the specific vulnerabilities of the community and the best actions to be pursued to address these issues. This will include actions to address current risks as well as future risks associated with climate change, including the potential impacts of sea level rise, increased storm frequencies and intensities, increased rates of erosion, salt water intrusion, wetland loss, and other impacts.

### GEOGRAPHIC LOCATION:

Town of Bowers Beach, Kent County, Delaware.

### OUTCOME:

The final outcome will be an action plan of prioritized projects designed to make the community more resilient, or at a minimum be prepared to recover, from damages associated with coastal hazards. The Town will also acquire the skills necessary to identify and seek out funding opportunities to finance project implementation.

### ACTIVITIES/SCHEDULE:

1. *Phase I-Data Collection and Synthesis:* This first phase of the project will include the collection, analysis, and dissemination of existing information to provide information to community members about their current storm flooding risk and vulnerabilities.
2. *Phase II-Vulnerability Assessment:* Phase two will include a detailed workshop(s) to gather further information and to conduct a detailed vulnerability assessment to be used as a guide for developing mitigation strategies and prioritizing mitigation projects. A Hazards Characterization workshop was conducted to collect the personal experiences from coastal storm and flooding events from the town residents, as well as to identify their initial concerns relating to these storm events. The information gathered during this workshop will be used by a technical workgroup, comprised of State and County experts in project planning and hazard preparations and town representatives, for development of a formal vulnerability assessment and initial mitigation strategy.

3. *Phase III-Strategy Development:* Phase three will utilize the detailed results of the vulnerability assessment to develop a final prioritization of needs and a set of strategies to address these needs.
4. *Phase IV-Implementation:* This phase will be a longer term effort to implement the action plan. Delaware Coastal Programs will take on an advisory role in assisting the town with procuring funding, project design and tracking.

Activity	# months req'd for completion	Estimated Completion Date	Status
<b>Phase I</b>	9	Winter 2010	Drainage Study ongoing; project webpage published
<b>Phase II</b>	9	Winter 2010	Hazard Workshop conducted and summary document completed;  Assessment workshop conducted; Assessment workshop evaluation ongoing.
<b>Phase III</b>	9	Winter 2010 Spring 2011	-----
<b>Phase IV</b>	12	Spring 2011	-----

**AGENCIES INVOLVED:**

Town of Bowers Beach

Division of Watershed Stewardship -Shoreline and Waterway Management Section and Drainage Section

Delaware Emergency Management Agency

Kent County Emergency Management

Federal Emergency Management Agency

Delaware Department of Transportation

UD Sea Grant

## POLICY DEVELOPMENT

### DEVELOPMENT OF A STATEWIDE SEA LEVEL RISE ADAPTATION PLAN

Sea level rise will have economic, social and environmental effects throughout the State of Delaware. Sea level rise increases the height of storm waves, making more areas vulnerable to storm damage and can inundate low lying areas, causing losses to tidal wetlands, habitat, and agricultural areas. Sea level rise also can cause higher water tables and salt water intrusion, interfering with the septic systems, drinking water and irrigation water. These effects have implications for coastal access and recreation, transportation networks, public safety and land use patterns.

To address these issues, the Delaware Coastal Programs will develop a Statewide Adaptation Plan for Sea Level Rise. Using the data and information collected from other parts of the Sea Level Rise Initiative in combination with the expertise of many other agencies, the adaptation plan will recommend policy changes and practices that will ensure that Delaware makes informed policy and investment decisions today to prevent damage and losses to infrastructure, resources and homes tomorrow. Recommendations will be based upon a careful assessment of potential effects to landowners, communities, economies, natural resources and infrastructure using the best available science and technology.

Development of the Sea Level Rise Adaptation Plan will be guided by an Advisory Committee that is comprised of representatives from state agencies, municipal governments, business and development advocacy groups and environmental advocacy groups. Significant opportunities for public involvement will also be integral to the development of the plan.

#### GEOGRAPHIC LOCATION:

This project will be statewide.

#### OUTCOMES:

The final outcome of this project will be the publication of a Statewide Sea Level Rise Adaptation Strategy that will outline recommended policies and management strategies to reduce the State's vulnerability to the impacts of Sea Level Rise.

Additional outcomes will include:

- Proceedings Document: Sea Level Rise Issues Characterization Workshop
- Statewide Assessment of Delaware's Vulnerability to Sea Level Rise
- Proceedings Document: Sea Level Rise Adaptation Strategies Workshop
- Increased awareness of the impacts of Sea Level Rise at the state and local level
- Increased interagency coordination on Sea Level Rise issues
- Public outreach
- Implementation of strategies

#### ACTIVITIES/SCHEDULE:

1. *Initial Issues Characterization Workshop:* One-day workshop to begin discussing and outlining potential impacts of sea level rise in Delaware. This workshop was held in March, 2009.
2. *Formation of Advisory Committee:* Agencies and organizations will be invited to participate in the Sea Level Rise Advisory Committee and monthly meetings will convene.
3. *Vulnerability Assessment:* Advisory Committee and Delaware Coastal Programs staff will conduct a statewide screening assessment of Delaware's potential vulnerability to sea level rise.
4. *Strategy Development:* Recommendations for strategies to reduce Delaware's future vulnerability to sea level rise will be drafted by the Advisory Committee and during a public workshop. These strategies will be refined and made available to the public for comment prior to finalizing the document.
5. *Implementation of Priority Strategies:* Strategies will be ranked by the Advisory Committee. Funding and other resources will be sought to implement priority strategies.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	2	March 2009	Completed
2	2	November 2010	Underway
3	6	February 2011	Underway
4	8	October 2011	Not yet begun
5	**	**	Not yet begun

\*\* Implementation will be an on-going task with no certain end date

#### AGENCIES INVOLVED:

The following agencies and organizations were invited to participate in the Advisory Committee:

Delaware Department of Agriculture

Delaware Department of Health and Social Services

Delaware Department of Natural Resources and Environmental Control

Delaware Department of Transportation

Delaware Department of Safety and Homeland Security

Delaware Economic Development Office

Delaware Farm Bureau  
Delaware Insurance Office  
Delaware League of Women Voters  
Delaware Nature Society  
Delaware Office of Management and Budget  
Delaware Office of the Governor  
Delaware Realtors Association  
Delaware State Chamber of Commerce  
Home Builders Association of Delaware  
The Nature Conservancy, Delaware Chapter  
Positive Growth Alliance  
Tidewater Utilities, Inc.  
University of Delaware College of Earth Ocean and the Environment

## MID-ATLANTIC REGIONAL COUNCIL ON THE OCEANS (MARCO)

In June 2009 the Governors of Delaware, Maryland, New Jersey, New York, and Virginia convened a summit to mark the signing of the *Mid-Atlantic Governors' Agreement on Ocean Conservation* and the establishment of the Mid-Atlantic Regional Council on the Ocean (MARCO). Discussions held at the Governors Summit built on expert knowledge and led to the identification of initial actions that advance each of the Governors' four shared priorities. Under the MARCO umbrella the five states are working together to address the four priority issue areas which include: protection of sensitive and unique offshore habitat areas; support for the sustainable development of offshore renewable energy; prepare the region's coastal communities for the impacts of climate change on ocean and coastal resources; and promote improvements in the region's coastal water quality. MARCO has recently added a fifth priority to address coastal and marine spatial planning (CMSP) in light of the President's Ocean Policy Task Force recommendations to develop a national framework for CMSP. CMSP is seen by MARCO as a means to advance most, if not all, of the four priorities and each state is taking steps to aid in the development, coordination, and integration of coastal and marine spatial plans for the region.

The Governors Agreement also called for MARCO to hold a Stakeholder Workshop on the initial action plan. In December 2009, key state and federal agency representatives along with high-profile leaders of the full range of ocean interests learned from each other, deliberated, and made commitments to advancing MARCO's shared actions on its priority areas. Based on the valuable feedback and dialogue from the stakeholder workshop, MARCO is collaborating with federal partners to implement the priority actions and is drafting an updated action plan. The DCP hosted two two-day MARCO working meetings in May and August 2010 to further the state-federal partnerships and the updated action plan.

More information can be found on the MARCO website: [www.midatlanticocean.org](http://www.midatlanticocean.org).

### GEOGRAPHIC LOCATION:

Mid-Atlantic region, including the states of Delaware, New York, New Jersey, Maryland, and Virginia.

### OUTCOME:

MARCO will result in improved management of Mid-Atlantic coastal and ocean resources. The collaborative effort will improve outcomes by instituting a regional, ecosystem-based approach and will foster a cooperative and constructive relationship among the states. It will also provide leverage for greater federal investment and action on the states' coastal and ocean management priorities.

### ACTIVITIES/SCHEDULE:

1. *Refine action plan and implement recommendations:* The action plan will be refined based upon the results of the December 2009 stakeholder workshop, the Presidents' Ocean Policy Task Force recommendations and National Ocean Policy, and the recent two day workshop with federal representatives held in August 2010. The plan outlines the goals, specific objectives, and initial actions for each of the four priority areas. Each initial action specifies which state will take the lead on it, which objective(s) it advances, and a proposed timeframe or completion date.

2. *Working Meetings:* The DCP will host and/or attend quarterly/triannual MARCO working meetings for both state and federal representatives.
3. *Stakeholder Engagement:* MARCO is in the process of applying for Federal grant funds to help organize and facilitate stakeholder engagement workshop(s).
4. *ELI Policy Review:* The DCP has contracted with the Environmental Law Institute (ELI) to conduct a detailed review and assessment of the laws, policies, and programs related to offshore renewable energy development activities in the Mid-Atlantic states coastal zones and adjacent federal waters. This will focus on Delaware, but also include information from the other five MARCO states. ELI began work in September 2010 and is on schedule to complete by April 2011.
5. *Regional SLR Adaptation:* The DCP is the lead on addressing MARCO's goal of preparing the region for sea level rise impacts on regional infrastructure, coastal habitat, and shoreline management. DCP will guide the development of vulnerability assessments and sea level rise scenarios for the MARCO region and to promote regional information exchange about adaptation across the states.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	12	June 2011	In progress
2	12	October 2011	In progress
3	24	October 2012	Not yet initiated
4	6	March 2011	In progress
5	2	October 2012	In progress

**AGENCIES INVOLVED:**

States of Delaware, New York, New Jersey, Maryland, and Virginia

## SUSTAINABLE COASTAL COMMUNITIES

Most land use decisions in Delaware are made at the local level, yet those making decisions often lack technical expertise and/or planning resources. To address the lack of technical and planning resources, the Delaware Coastal Programs offers grants and technical assistance to local governments, state agencies and not-for-profit organizations for planning, natural resource management and coastal hazard mitigation.

In previous years, this funding and technical assistance has helped communities develop ordinances, incorporate natural resource considerations into comprehensive land use plans, inventory natural resources and restore important coastal habitats. In 2009 and beyond, the grant program will be more focused towards assisting community planning for reducing impacts resulting from coastal hazards and assessing vulnerabilities and risks to plan for future impacts of sea level rise.

### GEOGRAPHIC LOCATION:

Grants will be available Statewide, through a competitive RFP process.

### OUTCOME:

This program will result in improved management of Delaware's coastal resources through incorporation of coastal hazard and natural resource considerations into local comprehensive plans. This includes coastal storm resiliency planning, development of coastal management ordinances to reduce impacts, and educational outreach for Delaware's local governments.

The DCP anticipates funding and assisting with 3 – 5 projects per year.

### ACTIVITIES/SCHEDULE:

1. *Release RFP and Award Grants:* The funding will be announced through a “Request for Proposals.” Grant proposals received will be ranked by a committee of resource experts and successful grant applicants will be notified.
2. *Grants Management:* DCP staff will negotiate contracts for each grant recipient and will provide technical assistance until the project has been completed.

Activity	# months req'd for completion	Estimated Completion Date	Status
1	4	December 2010	Underway
2	14	March 2012	Not yet underway

### AGENCIES INVOLVED:

Delaware Coastal Programs

## COMMUNICATION, TRAINING AND PUBLIC INVOLVEMENT

### COMPREHENSIVE MARKETING & OUTREACH STRATEGY FOR SEA LEVEL RISE

In order to effectively communicate to the public and decision maker audiences regarding sea level rise issues, the Delaware Coastal Programs (DCP) established a Sea Level Rise Outreach Strategy Committee comprised of educators, marketers, and communication specialists from the Delaware National Estuarine Research Reserve, Delaware Sea Grant, the Partnership for the Delaware Estuary, DNREC – Public Affairs, DNREC – Shoreline and Waterway Section, in addition to staff from DCP to develop a comprehensive sea level rise marketing and outreach strategy. The strategy provides a clear, coordinated message with information and materials developed and disseminated by all of the organizations of the Committee including Delaware Coastal Programs, Delaware National Estuarine Research Reserve.

As part of the development of this comprehensive strategy, a statewide survey to gauge public knowledge and opinions on sea level rise and its impacts on Delaware was completed in the spring of 2010. This survey provides information about Delaware residents' awareness and understanding of key issues regarding climate change and sea level rise; determine their perception of its overall effect on the economy and ecology of the state; and explore public opinion regarding long range planning for sea level rise loss and damage prevention. Using the results of this survey, as well as other studies and reports focused on improving communications on sea level rise and climate change, a comprehensive marketing and outreach strategy has been drafted to enhance the public and coastal stakeholders' awareness and response to sea level rise.

The strategy considers a variety of audiences (such as local, county, and state government officials, local and regional planners, economic development representatives, agriculture representatives, university researchers, educators, and property owners) and includes workshops, seminars, brochures, factsheets, public service announcements, media buys, website development and/or outreach displays.

#### GEOGRAPHIC LOCATION:

Statewide

#### OUTCOME:

A comprehensive marketing and outreach strategy and an implementation/work plan have been drafted.

#### ACTIVITIES/SCHEDULE:

1. *Strategy Development:* An inventory of existing Sea Level Rise marketing and outreach programs will be completed and will be analyzed along with results of the Sea Level Rise Attitudes and Perception Survey. This analysis will then be interpreted to design a targeted Marketing and Outreach program.
2. *Strategy Implementation:* Activities listed in the strategy will be implemented.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	4	Fall 2010	Draft Completed
<b>2</b>	Ongoing as needed	-	Underway

AGENCIES INVOLVED:

DNREC

Delaware Coastal Programs

Division of Watershed Stewardship/Shoreline & Waterway Management

Public Affairs

Delaware Sea Grant

Partnership for the Delaware Estuary

Responsive Management

## SEA LEVEL RISE INTERNET MAP VIEWER

Land-use decisions in Delaware are primarily made at the local level yet, often these smaller towns lack the GIS infrastructure that would allow large scale planning efforts, particularly those related to coastal hazards. Delaware Coastal Programs has made significant investment in GIS data, personnel, and hardware over the years. Transferring the benefits of this investment to community decision makers is vital to the success of these planning efforts.

As part of DCP's efforts assisting local governments with Coastal Hazard and Community Resilience Planning, data will be created and shared with the local decision makers and the community. Internet based mapping applications can be a useful tool to affect this sharing. Most local governments and citizens have access to basic internet browsers either at home or in public libraries. Online mapping tools such as Google Maps and Virtual Earth provide free, lightweight mapping tools that members of the public can use to participate in planning efforts. More robust applications, such as ArcGIS Server and Google Earth, allow for more complex views of Community Resiliency information while keeping costs at a minimum (i.e. free to end user). The choice of tool used will depend on the needs of the user and the ability of the tool to present the data.

DCP has utilized ArcGIS Server to produce and distribute Statewide Sea Level Rise Inundation maps for these planning efforts. KML versions of the data are available, however, the datasets are too large to be conveniently accessed on slower internet connections. ArcGIS Server provides both a freely accessible viewer for the general public and advanced access for GIS users to a map service.

### GEOGRAPHIC LOCATION:

Maps of DNEC's Sea Level Rise Inundation Scenarios are available statewide. Distribution of more localized data will initially focus on individual communities undergoing resiliency planning (i.e. Town of Bowers and City of New Castle).

### OUTCOME:

Website(s) providing citizen access to Community Resilience Planning Maps.

<http://www.dnrec.delaware.gov/Pages/SLRMaps.aspx>

### ACTIVITIES/SCHEDULE:

1. *Software needs assessment and acquisition:* Evaluate capabilities of various software to provide mapping data to public through open GIS browsers. Acquire selected software.
2. *Data List:* Develop and initial list of data to be distributed to community members.
3. *Data Conversion:* Convert selected data and maps for distribution.
4. *Website creation:* Establish a new set of pages within DCP's Sea Level Rise web section for distribution of mapping information.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	1 month		Complete
<b>2</b>	1 month		Complete
<b>3</b>	1 month		Complete
<b>4</b>	1 month		Complete

AGENCIES INVOLVED:

Delaware Coastal Programs

DNREC – Office of Information Technology

## STATEWIDE SURVEY TO GAUGE PUBLIC KNOWLEDGE AND OPINIONS ON SEA LEVEL RISE AND ITS IMPACT IN DELAWARE

In order to effectively plan and target sea level rise outreach and technical assistance, it is important to understand the public perception of sea level rise. However, there is currently no statewide information available regarding the level of knowledge Delawareans possess regarding sea level rise and its future impacts; nor whether Delawareans are motivated to change their behaviors to reduce their risk to impacts associated with sea level rise.

In order to address this need, the Delaware Coastal Programs, in cooperation with The Nature Conservancy and with contractual assistance from Responsive Management Inc. conducted a statewide telephone survey during the fall 2009. The survey was designed to be statistically significant and to assess Delaware residents' awareness and understanding of key issues regarding climate change and sea level rise; to determine their perception of its overall effect on the economy and ecology of the state; and to explore public opinion regarding long range planning for sea level rise loss and damage prevention.

The survey was completed in January 2010 and is available for download online:  
<http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/SLRSurveyReport.pdf>

### GEOGRAPHIC LOCATION:

The telephone survey was conducted statewide.

### OUTCOME:

The survey resulted in a written report that includes a summary of results; discussion of data analysis and statistical procedures, a tabular data report, survey graphs and tables, frequency distributions and cross-tabulations. The report has since been used to help in the development of an outreach and marketing strategy, and to guide the content of other outreach and educational products.

### ACTIVITIES/SCHEDULE:

1. *Develop survey instrument:* In cooperation with other interested agencies and Responsive Management, design and test the survey.
2. *Conduct Telephone Survey:* Responsive Management will conduct the phone survey using random dialing.
3. *Analyze Results:* Responsive Management will analyze the results of the survey with appropriate statistical tests.
4. *Prepare Report:* Responsive Management will prepare a final report that provides an executive summary, methodology, data and appropriate charts and graphs.
5. *Distribute and Explain Report:* Final report will be made available via the web and hard copy. Workshops will be held in cooperation with the Nature Conservancy and Responsive Management to explain the results of the survey.

<b>Activity</b>	<b># months req'd for completion</b>	<b>Estimated Completion Date</b>	<b>Status</b>
<b>1</b>	2	July 2009	Complete
<b>2</b>	2	November 2009	Complete
<b>3</b>	2	December 2009	Complete
<b>4</b>	1	January 2010	Complete
<b>5</b>	6	March 2010	Complete

**AGENCIES INVOLVED:**

DNREC Delaware Coastal Programs

The Nature Conservancy

Responsive Management